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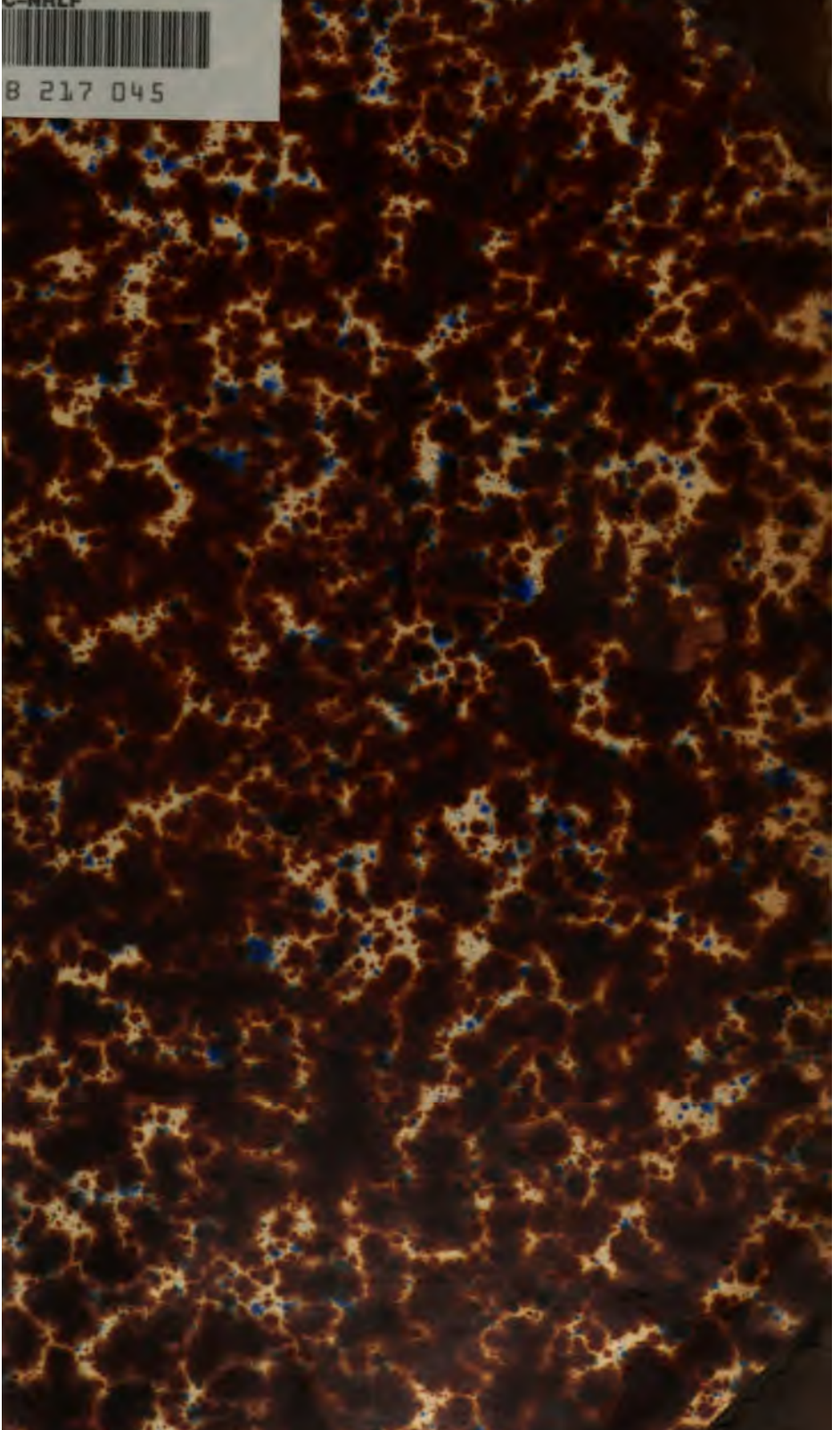

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PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.

TENTH MEETING,

HELD AT ALBANY, NEW YORK,

AUGUST, 1856.

CAMBRIDGE:
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1857.

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TABLE OF CONTENTS.

PAGE

Officers of the Association, ... viii
Committees, ... ix
Officers of the next Meeting, ... xi
Meetings of the Association, ... xii
Constitution of the Association, ... xiii
Resolutions and Enactments of a Permanent and Prospective Character, xx
List of Members, ... xxiii
Members Elected at the Albany Meeting, ... xlvi

Report on the Present State of our Knowledge of Linguistic Ethnology. By S. S. HALDEMAN, ... 1

COMMUNICATIONS.

A. MATHEMATICS AND PHYSICS.

MATHEMATICS.

1. On the Laws of Human Mortality. By C. F. M'CAY, ... 21
2. Investigation and Calculation of the Results of a Process of Causation. By JOHN PATERSON, ... 29
3. Vital Statistics. By E. B. ELLIOTT, ... 50

II. ASTRONOMY.

1. A simple Method of Correcting the common Nautical Method of "Double Altitudes" of the Sun, Moon, or a Planet, for the

Change of Declination between the Observations. By Prof. W. CHAUVENET, ... 101
2. On a Method of Determining the Latitude of a Place from the observed Times when two known Stars arrive at the same Altitude. By Prof. W. CHAUVENET, ... 103
3. On a New Method of Measuring Celestial Arcs. By ALVAN CLARK, ... 108
4. The Stability of Satellites revolving in Small Orbits. By DANIEL VAUGHAN, ... 111
5. On the Meridian Instruments of the Dudley Observatory. By Dr. B. A. GOULD, ... 113

III. PHYSICS AND CHEMISTRY.

1. On Acoustics applied to Public Buildings. By Prof. JOSEPH HENRY, ... 119
2. On the Sulphuric Acid Barometer. By Prof. JOSEPH HENRY, 135
3. Some Experiments on Visual Direction. By Prof. JOHN BROCKLESBY, ... 139
4. Redetermination of the Atomic Weight of Lithium. By Prof. J. W. MALLET, ... 144
5. Ammonia in the Atmosphere. By Prof. E. N. HORSFORD, . . 145

IV. PHYSICS OF THE GLOBE.

1. Approximate Cotidal Lines of Diurnal and Semi-Diurnal Tides of the Coast of the United States on the Gulf of Mexico. By A. D. BACHE, ... 153
2. Notes on the Progress made in the Coast Survey, in Prediction Tables for the Tides of the United States Coast. By A. D. BACHE, ... 166
3. Observations to determine the Cause of the Increase of Sandy Hook, made by the Coast Survey for the Commissioners on Harbor Encroachments of New York. By A. D. BACHE, . 171
4. Notes of Observations to determine the Progress of the Tidal Wave of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments. By A. D. BACHE, . 173
5. Supplement to the Paper on the "Secular Variation in the Magnetic Declination on the Atlantic and Gulf Coast of the United States, from Observations in the 17th, 18th, and 19th Centuries," published in the Providence Proceedings of the Association. By CHARLES A. SCHOTT, ... 173

6. Discussion of the Secular Variation of the Magnetic Inclination in the North-eastern States. By CHARLES A. SCHOTT, . . 177
7. On the General Distribution of Terrestrial Magnetism in the United States, from Observations made in the United States Coast Survey and Others. By A. D. BACHE, and J. E. HILGARD, . 187

V. METEOROLOGY.

1. On the Spirality of Motion in Whirlwinds and Tornadoes. By W. C. REDFIELD, ... 212
2. On Various Cyclones or Typhoons of the North Pacific Ocean; with a Chart, showing their Courses or Progression. By W. C. REDFIELD, ... 214
3. On the Avoidance of the Violent Portions of Cyclones, with Notices of a Typhoon at the Bonin Islands. By JOHN ROGERS, U. S. N., and ANTON SCHÖNBORN, ... 222
4. Results of a Series of Meteorological Observations made at New York Academies from 1826 to 1850. By FRANKLIN B. HOUGH, 231
5. On the Peculiar Appearance of the Atmosphere on the 23d of May, 1856, at St. Martin's, Isle Jesus, Canada East. By Prof. CHARLES SMALLWOOD, ... 237

PART II.

B. NATURAL HISTORY.

I. GEOLOGY AND GEOGRAPHY.

1. Plan of Development in the Geological History of North America. With a Map. By Prof. JAMES D. DANA, ... 1
2. On the Parallelism of the Rock Formations of Nova Scotia with those of other parts of America. By Prof. J. W. DAWSON, . 18
3. Geological Observations on the Pluto-volcanic Slope of the Sierra Madre along the Azimuth Boundary Line through North-west Sonora. By ARTHUR SCHOTT, ... 25
4. On the Carboniferous Limestones of the Mississippi Valley. By Prof. JAMES HALL, ... 51
5. Remarks on Niagara Falls. By Prof. L. R. GIBBES, . . . 69
6. On the Broadtop Coal Basin in Central Pennsylvania. With a Map. By J. P. LESLEY, ... 78

7. Notes on the Geology of Middle and Southern Alabama. By Prof. A. WINCHELL, ... 82
8. Statistics of some Artesian Wells of Alabama. By Prof. A. WINCHELL, ... 94
9. On the Agency of the Gulf-Stream in the Formation of the Peninsula of Florida. By JOSEPH LECONTE, ... 103
10. Observations on the Orography of the Western portion of the United States. With a Map. By WILLIAM P. BLAKE, . . 119
11. General Description of the Country adjacent to the Boundary between the United States and Mexico. By Col. W. H. EMORY, 134

II. PALEONTOLOGY.

1. On the Geological Position of the Deposits in which occur the Remains of the Fossil Elephant of North America. By J. W. FOSTER, ... 148
2. Notes on the Teeth of an Elephant discovered near Zanesville, Ohio. By Prof. J. WYMAN, ... 169
3. On a Batrachian Reptile from the Coal Formation. By Prof. J. WYMAN, ... 172
4. Remains on a Specimen of Fossil Wood from the Devonian Rocks, (*Gaspé Sandstones*) or Gaspe, Canada East. By J. W. DAWSON, ... 174
5. Observations on the genus Archimedes, or Fenestella, with Descriptions of Species, etc. By Prof. JAMES HALL, ... 176
6. On the Relations of the Fossil Fishes of the Sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic Periods. By W. C. REDFIELD, ... 180
7. On the Occurrence of Fish Remains in the Carboniferous Limestone of Illinois. By A. H. WORTHEN, ... 189

III. ZOÖLOGY.

1. On the Names of Animals and Plants, with Reference to the Origin of Languages, and to the Countries where Nations passed their Childhood. By Dr. DAVID F. WEINLAND, ... 193
2. On the Digestive Apparatus of the Acanthocephala. By Dr. DAVID F. WEINLAND, ... 197

IV. PHILOLOGY AND ETHNOLOGY.

1. On the Relations between Chinese and the Indo-European Languages. By S. S. HALDEMAN, ... 201
2. Supposed Runic Inscriptions. By A. C. HAMLIN, ... 214

C. PRACTICAL SCIENCE.

I. MECHANICS.

1. On Efflorescence from Brick Masonry. By Lieut. E. B. Hunt, . 216

II. MISCELLANEOUS.

1. On Systematizing the Abbreviations of Titles of Periodicals, Transactions, etc. By Lieut. E. B. Hunt, ... 218

Papers Presented, but not Published, ... 222

EXECUTIVE PROCEEDINGS.

History of the Meeting, ... 229
Opening Address, by the President, ... 230
Welcome, by Hon. A. J. Parker, ... 232
Officers Elected, ... 235
Festivities, ... 236
Invitations, ... 236
Resolutions Adopted, ... 240
Votes of Thanks, ... 237
Notice of Dr. T. Romeyn Beck, ... 241
Report of Joseph Lovering, Permanent Secretary, ... 244
Report of the Auditors, ... 246
Cash Account of the Permanent Secretary, ... 248
Stock Account of the Permanent Secretary, ... 250
Report of the Treasurer, ... 252
Report of the Auditors, ... 252

Index, ... 253

OFFICERS OF THE ASSOCIATION

AT THE

ALBANY MEETING.

Prof. JAMES HALL, *President.*
Prof. JOSEPH LOVERING, *Permanent Secretary.*
Dr. B. A. GOULD, Jr., *General Secretary.*
Dr. A. L. ELWYN, *Treasurer.*

Standing Committee.

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Prof. JOSEPH LOVERING,
Dr. B. A. GOULD, Jr.,
Dr. A. L. ELWYN,
Prof. JOHN TORREY,
Prof. WOLCOTT GIBBS,
Prof. A. D. BACHE,
Prof. ALEXIS CASWELL,
Prof. JEFFRIES WYMAN,
Dr. JOHN L. LECONTE,
Sir WILLIAM E. LOGAN,
Prof. J. H. C. COFFIN,

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G. Y. LANSING, *Chairman.*

S. B. WOOLWORTH,
JOHN E. GAVIT,
JOHN PATERSON,
} *Secretaries.*

Gov. MYRON H. CLARK,
THOMAS W. OLCOTT,
JOHN N. CAMPBELL,
EZRA P. PRENTICE,
JOHN V. L. PRUYN,
THOMAS HUN,

Stephen Van Rensselaer,
Gideon Hawley,
William B. Sprague,
Amasa J. Parker,
B. P. Johnson,
Joel T. Headley,
James H. Armsby,
Erastus Corning,
Daniel D. Barnard,
I. N. Wyckoff,
Thurlow Weed,
Ira Harris,
Amos Dean.

SPECIAL COMMITTEES.

A. Committees continued from Former Meetings.

Committee to Memorialize the Legislature of Ohio on the Subject of a Geological Exploration of that State.

Dr. J. P. Kirtland, Cleveland.
Gov. S. P. Chase, Columbus.
Hon. Thomas Erving, Lancaster.
Judge George Hoadley, Jr., Cincinnati.
Gen. C. B. Goddard, Zanesville.
Pres. J. W. Andrews, Marietta.
Prof. Joseph Henry, Washington.
Prof. J. D. Dana, New Haven.
Prof. Louis Agassiz, Cambridge.

Committee to Report in Relation to Uniform Standards in Weights, Measures, and Coinage.

Prof. A. D. Bache,
Prof. Joseph Henry,
Prof. J. H. Alexander,
Prof. John F. Frazer,
Prof. Wolcott Gibbs,
Prof. Benjamin Peirce,
Prof. John Leconte,
Prof. W. B. Rogers,
Dr. J. H. Gibbon,
Dr. B. A. Gould, Jr.,
Prof. J. Lawrence Smith,
Prof. R. S. McCulloch.

Committee to Audit the Accounts of the Treasurer, and Permanent Secretary.

Prof. J. H. C. COFFIN, | Dr. J. L. LECONTE.

B. NEW COMMITTEES.

Consulting Committee on the Publication of the Albany Proceedings.

Prof. BENJAMIN PEIRCE, | Prof. E. N. HORSFORD.
Prof. LOUIS AGASSIZ, |

Committee to Memorialize the Legislature of New York in Reference to Fish-Breeding.

Prof. LOUIS AGASSIZ, | Prof. J. D. DANA.

OFFICERS OF THE MONTREAL MEETING.

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Prof. ALEXIS CASWELL, *Vice-President.*
Prof. JOSEPH LOVERING, *Permanent Secretary.*
Dr. JOHN LECONTE, *General Secretary.*
Dr. A. L. ELWYN, *Treasurer.*

Standing Committee.

Prof. J. W. BAILEY,
Prof. JOSEPH LOVERING,
Prof. JOHN LECONTE.
Dr. A. L. ELWIN,
Prof. JAMES HALL,
Dr. B. A. GOULD, Jr.

Local Committee.

Sir WILLIAM E. LOGAN, *Chairman.*

THE MAYOR OF THE CITY,
THE PRESIDENT OF THE BOARD OF TRADE,
THE PRESIDENT OF THE NATURAL HISTORY SOCIETY,
Sir LOUIS LAFONTAINE,
Hon. P. J. O. CHAUVEAU,
L. H. HALTON, Esq.,
H. LYMAN, Esq.,
Hon. Judge DAY,
A. A. DONAN, Esq.,
Hon. P. D. BEAUJEU.

MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

	Place.	Date.	President.	General Secretary.	Permanent Secret'y.	Treasurer.
1st Meeting,	Philadelphia, Pa.,	September 20, 1848,	W. C. Redfield, Esq.,	Prof. Walter R. Johnson,	. . .	Prof. J. Wyman.
2d "	Cambridge, Mass.,	August 14, 1849,	Prof. Joseph Henry,	Prof. E. N. Horsford,	. . .	Dr. A. L. Elwyn.
3d "	Charleston, S. C.,	March 12, 1850,	Prof. A. D. Bache,*	Prof. L. R. Gibbes,*	. . .	Dr. St. J. Ravenel.*
4th "	New Haven, Ct.,	August 19, 1850,	Prof. A. D. Bache,	E. C. Herrick, Esq.,	. . .	Dr. A. L. Elwyn.
5th "	Cincinnati, Ohio,	May 5, 1851,	Prof. A. D. Bache,	Prof. W. B. Rogers,	Prof. S. F. Baird,	Dr. A. L. Elwyn.
6th "	Albany, N. Y.,	August 19, 1851,	Prof. L. Agassiz,	Prof. W. B. Rogers,	Prof. S. F. Baird,	Dr. A. L. Elwyn.
7th "	Cleveland, Ohio.,	July 28, 1853,	Prof. Benj. Peirce,	Prof. J. D. Dana,	Prof. S. F. Baird,	Dr. A. L. Elwyn.
8th "	Washington, D.C.,	April 26, 1854,	Prof. J. D. Dana,	Prof. J. Lawrence Smith,	Prof. J. Lovering,	Dr. J. L. LeConte.*
9th "	Providence, R. I.,	August 15, 1855,	Prof. John Torrey,	Prof. Walcott Gibbs,	Prof. J. Lovering,	Dr. A. L. Elwyn.
10th "	Albany, N. Y.,	August 20, 1856,	Prof. James Hall,	Dr. B. A. Gould, Jr.,	Prof. J. Lovering,	Dr. A. L. Elwyn.

* In the absence of the regular officer.

CONSTITUTION OF THE ASSOCIATION.*

OBJECTS.

THE Association shall be called "The American Association for the Advancement of Science." The objects of the Association are by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of the United States; to give a stronger and more general impulse, and a more systematic direction to scientific research in our country; and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS.

RULE 1. Members of scientific societies, or learned bodies having in view any of the objects of this Association, and publishing transactions, shall be considered members on subscribing these rules.

RULE 2. Collegiate professors, also civil engineers and architects who have been employed in the construction or superintendence of public works, may become members on subscribing these rules.

RULE 3. Persons not embraced in the above provisions may become members of the Association upon recommen-

* Adopted August 25, 1856, and ordered to go into effect at the opening of the Montreal Meeting.

dation in writing by two members, nomination by the Standing Committee, and election by a majority of the members present.

OFFICERS.

RULE 4. The officers of the Association shall be a President, Vice-President, General Secretary, Permanent Secretary and Treasurer. The President, Vice-President, General Secretary and Treasurer, shall be elected at each meeting for the following one; — the three first-named officers not to be reëligible for the next two meetings, and the Treasurer to be reëligible as long as the Association may desire. The Permanent Secretary shall be elected at each second meeting, and also be reëligible as long as the Association may desire.

MEETINGS.

RULE 5. The Association shall meet, at such intervals as it may determine, for one week or longer — the time and place of each meeting being determined by a vote of the Association at the previous meeting; and the arrangements for it shall be intrusted to the officers and the Local Committee.

STANDING COMMITTEE.

RULE 6. There shall be a Standing Committee, to consist of the President, Vice-President, Secretaries, and Treasurer of the Association, the officers of the preceding year, the permanent chairmen of the Sectional Committees, after these shall have been organized, and six members present from the Association at large who shall have attended any of the previous meetings, to be elected upon open nomination by ballot on the first assembling of the Association. A majority of the whole number of votes cast to elect. The General Secretary shall be Secretary of the Standing Committee.

The duties of the Standing Committee shall be, —

1. To assign papers to the respective sections.

2. To arrange the scientific business of the general meetings, to suggest topics and arrange the programmes for the evening meetings.

3. To suggest to the Association the place and time of the next meeting.

4. To examine, and, if necessary, to exclude papers.

5. To suggest to the Association subjects for scientific reports and researches.

6. To appoint the Local Committee.

7. To have the general direction of publications.

8. To manage any other general business of the Association during the session, and during the interval between it and the next meeting.

9. In conjunction with four from each section, to be elected by the sections for the purpose, to make nominations of officers of the Association for the following meeting.

10. To nominate persons for admission to membership.

11. Before adjourning, to decide which papers, discussions, or other proceedings shall be published.

SECTIONS.

RULE 7. The Association shall be divided into two Sections, and as many sub-Sections as may be necessary for the scientific business, the manner of division to be determined by the Standing Committee of the Association. The two Sections may meet as one.

SECTIONAL OFFICERS AND COMMITTEES.

RULE 8. On the first assembling of the Section, the members shall elect upon open nomination a permanent chairman and secretary, also three other members to constitute with these officers a Sectional Committee.

The Section shall appoint, from day to day, a chairman to preside over its meetings.

RULE 9. It shall be the duty of the Sectional Committee

of each section, to arrange and direct the proceedings in their Section; to ascertain what communications are offered; to assign the order in which these communications shall appear, and the amount of time which each shall occupy.

The Sectional Committees may likewise recommend subjects for systematic investigation by members willing to undertake the researches, and to present their results at the next meeting.

The Sectional Committees may likewise recommend reports on particular topics and departments of science, to be drawn up as occasion permits, by competent persons, and presented at subsequent meetings.

REPORTS OF PROCEEDINGS.

RULE 10. Whenever practicable, the proceedings shall be reported by professional reporters or stenographers, whose reports are to be revised by the secretaries before they appear in print.

PAPERS AND COMMUNICATIONS.

RULE 11. No paper shall be placed in the programme, unless admitted by the Sectional Committee; nor shall any be read, unless an abstract of it has been previously presented to the Secretary of the Section, who shall furnish to the chairman the titles of papers of which abstracts have been received.

RULE 12. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declare such to be his wish before presenting it to the Association.

RULE 13. Copies of all communications, made either to the General Association or to the Sections, must be furnished by the authors; otherwise only the titles or abstracts shall appear in the published proceedings.

RULE 14. All papers, either at the general or in the Sectional meetings, shall be read, as far as practicable, in

the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the proper Sectional Committee.

RULE 15. If any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

RULE 16. No exchanges shall be made between members without authority of the respective Sectional Committees.

GENERAL AND EVENING MEETINGS.

RULE 17. The Standing Committee shall appoint any general meeting which the objects and interests of the Association may call for, and the evenings shall, as a rule, be reserved for general meetings of the Association.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Sections.

It shall be a part of the business of these general meetings to receive the Address of the President of the last meeting; to hear such reports on scientific subjects as, from their general importance and interests, the Standing Committee shall select; also to receive from the chairmen of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

RULE 18. The Association shall be called to order by the President of the preceding meeting, and this officer having resigned the chair to the president elect, the general Secretary shall then report the number of papers relating to each department which have been registered, and the

Association consider the most eligible distribution into Sections, when it shall proceed to the election of the additional members of the Standing Committee in the manner before described; the meeting shall then adjourn, and the Standing Committee, having divided the Association into Sections as directed, shall allot to each its place of meeting for the Session. The Sections shall then organize by electing their officers and their representatives in the Nominating Committee and shall proceed to business.

PERMANENT SECRETARY.

RULE 19. It shall be the duty of the Permanent Secretary to notify members who are in arrears, to provide the necessary stationery and suitable books for the list of members and titles of papers, minutes of the general and sectional meetings, and for other purposes indicated in the rules, and to execute such other duties as may be directed by the Standing Committee or by the Association.

The Permanent Secretary shall make a report annually to the Standing Committee, at its first meeting, to be laid before the Association, of the business of which he has had charge since its last meeting.

All members are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

Whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the proceedings of the Association, he is authorized to commit the same to the author, or to the proper sub-committee of the Standing Committee for correction.

LOCAL COMMITTEE.

RULE 20. The Local Committee shall be appointed from among members residing at or near the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements and the necessary announcements for the meeting.

The Secretary of the Local Committee shall issue a circular in regard to the time and place of meetings, and other particulars, at least one month before each meeting.

SUBSCRIPTIONS.

RULE 21. The amount of the subscription, at each meeting, of each member of the Association shall be two dollars, and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. These subscriptions shall be received by the Permanent Secretary, who shall pay them over, after the meeting, to the Treasurer.

No person shall be considered a member of the Association until the subscription for the meeting at which he is elected has been paid.

RULE 22. The names of all persons two years in arrears for annual dues shall be erased from the list of members; provided that two notices of indebtedness, at an interval of at least three months, shall have been previously given.

ACCOUNTS.

RULE 23. The accounts of the Association shall be audited annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 24. No article of this constitution shall be altered, or amended, or set aside, without the concurrence of three fourths of the members present, and unless notice of the proposed change shall have been given at the preceding annual meeting.

RESOLUTIONS AND ENACTMENTS

OF A

PERMANENT AND PROSPECTIVE CHARACTER,

PASSED PREVIOUS TO THE TENTH MEETING.

Resolved, That a *manual* or *manuals of scientific observation and research*, especially adapted to the use of the American inquirer, comprising directions for properly observing phenomena in every department of physical science, and for making collections in natural history, etc., whether on land or at sea, is much needed at the present time; and that such a publication, placed in the hands of officers of the army and navy, would greatly tend to develop the natural resources of our extended country, and to the general advancement of science.

Resolved, That the American Association for the Advancement of Science cordially recommends the Smithsonian Institution to undertake the preparation of such a volume, under the editorial superintendence of its Secretary, to be published in its series of reports.

Resolved, That this Association will cordially coöperate in the production of such a manual or manuals, in whatever manner may be best adapted to secure the end in view.

(*Proceedings Second Meeting*, 1849, pp. 273, 351.)

Resolved, That a copy of the printed volume of Proceedings of the Meetings at Philadelphia, Cambridge, and New Haven be presented to the libraries of Harvard and Yale.

(*Proceedings Fourth Meeting*, 1850, p. 346.)

Resolved, That the Treasurer be requested to retain $300 of the funds in his hands, and belonging to the Association, for the purpose of paying the salary of the Permanent Secretary; said payment to be made at such time, and in such manner, as may be agreed upon by the Treasurer and Permanent Secretary.

Resolved, That copies of the Proceedings of the American Association be presented to the New York Lyceum and the Philadelphia Academy of Natural Sciences.

(*Proceedings Fourth Meeting*, 1850, pp. 390, 391.)

Resolved, That copies of the Proceedings of the American Association for the Advancement of Science be presented to the American Academy of Arts and Sciences, Boston; to the Boston Society of Natural History; to the New York Lyceum of Natural History; to the American Philosophical Society and to the Academy of Natural Sciences of Philadelphia; to the Smithsonian Institution; and to the Western Academy of Natural Sciences at Cincinnati.

(*Proceedings Fifth Meeting*, 1851, p. 249.)

Resolved, That the names of those only shall be entered in the list of members who shall have signified their acceptance.

(*Proceedings Seventh Meeting*, 1853.)

Resolved, That a sum not exceeding seventy-five dollars shall be paid to the Permanent Secretary, to defray the expenses necessary for attending each meeting of the Association.

(*Proceedings Seventh Meeting*, 1853.)

Resolved, That the following members be requested to report on the subjects respectively assigned to them, viz.: —

Prof. A. D. BACHE. *On Recent Additions to our Knowledge of the Theory of Tides.*

Prof. JOSEPH HENRY. *On Recent Additions to our Knowledge of the Laws of Atmospheric Electricity.*

Prof. JAMES HALL. *On Recent Additions to our Knowledge of the Paleozoic Rocks.*

Prof. J. L. SMITH. *On the Recent Progress of Micro-Chemistry.*

Prof. WOLCOTT GIBBS. *On the Recent Progress of Organic Chemistry.* (This Report was made at the Providence Meeting.)

Dr. JOSEPH LEIDY. *On the Remains of Fossil Reptiles and Mammals in North America.*

Prof. BENJAMIN PEIRCE. *On the Present State of the Theory of Planetary Perturbations.*

Dr. W. I. BURNET. *On Recent Advances in Anatomy and Physiology.*

Prof. J. D. DANA. *On the Geographical Distribution of the Lower Animals.*

Prof. LOUIS AGASSIZ. *On the History of our Knowledge of Alternation of Generation in Animals.*

Prof. S. S. HALDEMAN. *On the Present State of our Knowledge of Linguistic Ethnology.* (This Report was made at the Albany Meeting.)

Dr. B. A. GOULD, Jr. *On the Progress and Developments of the Electro-Chronographic Method of Observation.*

(*Proceedings Seventh Meeting*, 1853.)

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Morgan, Lewis H., Rochester, New York [10].
Morris, Margaretta H., Germantown, Pennsylvania [4].

*Morton, Dr. S. G., Philadelphia [1].
Munger, George G., Rochester, New York [10].
Munroe, Rev. Nathan, Bradford, Massachusetts [6].
Munsell, Joel, Albany [6].

N.

Nelson, J. P., Goldsboro, North Carolina [7].
Newberry, Dr. John S., Cleveland, Ohio [5].
Newcomb, Dr. Wesley, Albany [10].
Newton, Hubert A., Esq., New Haven, Connecticut [6].
Newton, John, Orange Hill, Washington Co., Florida [7].
Newton, Rev. E. H., Cambridge, New York [1].
Nichols, Dr. James R., Haverhill, Massachusetts [7].
Nichols, Prof. John A., New York [10].
*Nicollet, J. N., Esq., Washington, D. C. [1].
Norton, Rev. Niram, Fredonia, New York [8].
*Norton, Prof. J. P., New Haven, Connecticut [1].
Norton, Prof. W. A., New Haven, Connecticut [6].
Nott, Dr. J. C., Mobile, Alabama [3].

O.

*Oakes, William, Esq., Ipswich, Massachusetts [1].
O'Callaghan, E. B., M. D., Albany [10].
Olcott, Thomas W., Esq., Albany [2].
O'Leary, Prof. Charles, Emmetsburg, Maryland [10].
Oliver, James Edward, Lynn, Massachusetts [7].
*Olmsted, Alexander F., New Haven, Connecticut [4].
Olmsted, Charles H., Esq., E. Hartford, Connecticut [1].
Olmsted, Prof. D., New Haven, Connecticut [1].
*Olmsted, Denison, Jr., Esq., New Haven, Connecticut [1].
Olney, Stephen T., Providence [9].
Opdyke, George, New York [8].
Ordway, John M., Roxbury, Massachusetts [9].
Ormiston, Rev. William, Toronto, Canada [10].
Osborn, A., Esq., Albany, New York [1].
Osborn, H. S., Liberty, Bedford Co., Virginia [10].
Osgood, Rev. Samuel, D. D., New York [8].

Osten Sacken, Baron R. von, Washington, D. C. [10].
Otis, George A., Jr., Springfield, Massachusetts [10].

P.

Painter, Minshall, Lima, Delaware Co., Pennsylvania [7].
Palmer, Charles H., Portage Lake, Michigan [6].
Parker, Hon. Amasa J., Albany [6].
Parker, Prof. William H., Middlebury, Vermont [10].
*Parkman, Dr. Samuel, Boston [1].
Parry, Dr. Charles C., Davenport, Iowa [6].
Parsons, Dr. Charles H., Providence [9].
Parsons, Dr. Usher, Providence [9].
Parvin, Theodore S., Muscatine, Iowa [7].
Peale, Titian R., Esq., Washington, D. C. [1].
Peck, Lieut. G. W., U. S. T. E. [9].
Peirce, Prof. Benjamin, Cambridge, Massachusetts [1].
Pendleton, A. G., U. S. N., Washington, D. C. [7].
Perkins, Prof. G. R., Utica, New York [1].
Perry, Com. M. C., New York [10].
Peters, Dr. C. H. F., Albany [9].
Phelps, Philip, Jr., Hastings, New York [10].
Phelps, S. L., U. S. N., Washington, D. C. [8].
Pickering, Dr. Charles, Boston [1].
Pierce, Prof. William M., Petersburg, Virginia [10].
Pigott, A. Snowden, Baltimore [10].
Pitcher, Dr. Zina, Detroit, Michigan [1].
Pitman, Benn, Cincinnati [10].
Plant, I. C., Esq., Macon, Georgia [3].
*Plumb, Dr. Ovid, Salisbury, Connecticut [9].
Porter, Prof. John A., New Haven, Connecticut [4].
Potter, Rev. Dr. H. B., Albany [6].
Pourtales, L. F., Esq., Washington, D. C. [1].
Powers, A. E., Esq., Lansingburg, New York [1].
Prentice, E. P., Esq., Albany [2].
Prescott, Dr. William, Concord, New Hampshire [1].
Priest, Rev. J. A., Homer, New York [10].
Prince, W. R., Flushing, Long Island [10].
Prout, H. A., M. D., St. Louis, Missouri [7].

Pruyn, J. V. L., Esq., Albany [1].
Pruyn, Robert H., Albany [10].
Putnam, F. W., Salem, Massachusetts [10].
Pybos, Benjamin, Tuscumbia, Alabama [7].

R.

Randell, John, New York [8].
Rankin, Robert G., New York [10].
Ray, Dr. Isaac, Providence [9].
Redfield, John H., Esq., New York [1].
*Redfield, William C., Esq., New York [1].
Reid, D. B., London [10].
Renwick, Prof. James, New York [1].
Resor, Jacob, Cincinnati, Ohio [8].
Reuben, Levi, New York [10].
Rhees, William J., Washington, D. C. [8].
Rice, De Witt C., New York [7].
Rice, Henry, North Attleborough, Massachusetts [7].
Rice, W. H., Albany [10].
Richards, Rev. W. C., Providence [9].
Richmond, A. B., Meadville, Pennsylvania [8].
Riddell, Dr. John L., New Orleans [1].
Riddell, William P., New Orleans [7].
Ripley, Hezekiah W., Esq., Harlan, New York [6].
Ritchie, E. S., Boston [10].
Robb, Prof. James, M. D., Fredericton, New Brunswick [4].
Robertson, Thomas D., Rockford, Illinois [10].
Rockwell, Alfred P., New Haven, Connecticut [10].
Rockwell, John A., Norwich, Connecticut [10].
Rodman, William M., Providence [9].
*Rogers, Prof. James B., Philadelphia [1].
Rogers, Prof. Robert E., Philadelphia [1].
Rogers, Prof. W. B., Boston [1].
Rogers, William F., Philadelphia [10].
Rood, Ogden N., New Haven, Connecticut [7].
Roome, Martin R., New York [10].
Ruggles, Prof. William, Washington, D. C. [8].
Runkle, J. D., Esq., Cambridge, Massachusetts [2].

S.

Safford, Prof. J. M., Lebanon, Tennessee [6].
Sager, Prof. Abraham, Ann Arbor, Michigan [6].
Sanford, R. K., Riga, New York [7].
Sargent, Rufus, Auburn, New York [10].
Savage, Thomas S., Pass Christian, Mississippi [10].
Saville, Henry M., Syracuse, New York [10].
Saxton, Joseph D., Esq., Washington, D. C. [1].
Scarborough, Rev. George, Owensburg, Kentucky [2].
Schaeffer, Prof. George C., Washington, D. C. [1].
Schank, Dr. J. Stilwell, Princeton, New Jersey [4].
Schnee, Alexander, Madison, Wisconsin [10].
Schoolcraft, Henry R., Washington, D. C. [7].
Schott, Arthur C. V., Washington, D. C. [8].
Schott, Charles A., Washington, D. C. [8].
Selden, George M., Esq., Troy, New York [6].
Seropyan, Christopher, New Haven, Connecticut [10].
Sessions, Rev. John, Albany [6].
Sestini, Prof. Benedict, Georgetown, D. C. [8].
Seward, Hon. William H., Auburn, New York [1].
Shaefer, P. W., Pottsville, Pennsylvania [4].
Shaffer, David H., Cincinnati, Ohio [7].
Shane, J. D., Lexington, Kentucky [7].
Shaw, Edward, Washington, D. C. [9].
Sheldon, D. H., Racine, Wisconsin [10].
Shepard, Prof. C. U., New Haven, Connecticut [4].
Shippen, William, Washington, D. C. [8].
Shumard, B. F., M. D., St. Louis, Missouri [7].
Sias, Solomon, Fort Edwards, New York [10].
Sill, Hon. Elisha, Cuyhaoga Falls, Ohio [6].
Silliman, Prof. Benjamin, New Haven, Connecticut [1].
Silliman, Prof. Benjamin, Jr., New Haven, Connecticut [1].
Skilton, Dr. Avery J., Troy, New York [6].
Skinner, George W., M. D., Little Falls, New York [10].
Smallwood, Charles, M. D., St. Martin, Isle Jesus, Canada East [7].
Smith, Prof. Augustus W., Middletown, Connecticut [4].
Smith, Capt. E. R., U. S. A. [8].
Smith, Prof. Francis H., Charlottesville, Virginia [9].

Smith, George, Upper Darby, Delaware Co., Pennsylvania [7].
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*Smith, J. V., Esq., Cincinnati, Ohio [5].
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Smith, Sanderson, New York [9].
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Snow, Charles B., Washington, D. C. [8].
Snow, Edwin M., M. D., Providence [9].
Sparks, Jared, Cambridge, Massachusetts [2].
Spear, C. V., Pittsfield, Massachusetts [10].
Spencer, Thomas, Philadelphia [8].
Sprague, Charles Hill, Malden, Massachusetts [7].
Stanard, Benjamin A., Esq., Cleveland, Ohio [6].
Starr, William, Ceresco, Wisconsin [10].
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Stearns, Josiah A., Boston [10].
Stebbins, Rev. Rufus P., Cambridge, Massachusetts [2].
Steele, Samuel, Albany [10].
Steiner, Dr. Lewis H., Baltimore, Maryland [7].
Stetson, Charles, Cincinnati, Ohio [4].
Stevens, Prof. M. C., Richmond, Indiana [9].
Stevens, Robert P., M. D., Ceres, Alleghany Co., New York [7].
Stewart, Prof. William M., Clarksville, Tennessee [7].
Stillman, Dr. C. H., Plainfield, New Jersey [8].
Stillman, Dr. J. D. B., New York [8].
Stillman, Thomas B., New York [8].
Stone, Rev. Edwin M., Providence [9].
Storer, Dr. D. H., Boston [1].
Street, Alfred B., Albany [10].
Sturtevant, Pres. J. M., Jacksonville, Illinois [10].
Suckley, Dr. George, U. S. A. [9].
Sullivant, William S., Columbus, Ohio [7].
Sumner, George, Boston [8].
Sutherland, Prof. William, Montreal, Canada [6].
Swallow, G. C., Columbia, Missouri [10].

Swan, Gen. Lansing B., Rochester, New York [8].
Sweeney, Peter, Buffalo, New York [10].
Swinburne, John, Albany [6].

T.

Tabor, Azor, Albany [6].
Talcott, Andrew, Cincinnati, Ohio [7].
*Tallmadge, Hon. James, New York [1].
Tappan, Chancellor H. P., Ann Arbor, Michigan [10].
Tatlock, Prof. John, Williamstown, Massachusetts [10].
Tatum, Joel H., Baltimore, Maryland [10].
Taylor, George W., Albany [10].
Taylor, Dr. Julius S., Carrolton, Montgomery Co., Ohio [1].
Taylor, Morse K., M. D., Galesburg, Knox Co., Illinois [7].
*Taylor, Richard C., Esq., Philadelphia [1].
Tefft, Thomas A., New York [9].
*Teschemacher, J. E., Esq., Boston [1].
Tevis, Robert C., Esq., Shelbyville, Kentucky [5].
Thomas, William A., Irvington, N. Y. [10].
Thomas, Prof. W. H. B., Philadelphia [9].
Thompson, Dr. Alexander, Aurora, New York [6].
Thompson, Aaron R., New York [1].
Thompson, John A., M. D., Cayuga, New York [10].
Thompson, Dr. J. W., Wilmington, Delaware [9].
Thompson, John Edgar, Esq., Philadelphia [1].
*Thompson, Rev. Z., Burlington, Vermont [1].
Thorn, James, M. D., Troy, New York [10].
Thurber, George, Esq., New York [1].
Thurber, Isaac, Providence [9].
Tobey, Dr. Samuel B., Providence [9].
Torrey, Dr. John, New York [1].
Torrey, Prof. Joseph, Burlington, Vermont [2].
Totten, Gen. J. G., U. S. A., Washington, D. C. [1].
Town, Salem, Aurora, New York [7].
Townsend, Hon. Franklin, Albany [4].
Townsend, Dr. Howard, Albany [10].
*Townsend, John K., Esq., Philadelphia [1].
Townsend, Robert, Albany [9].

*Troost, Dr. Gerard, Nashville, Tennessee [1].
Trowbridge, Prof. W. P., Ann Arbor, Michigan [10].
Truesdell, Samuel, New York [10].
Trumbull, James H., Esq., Hartford, Connecticut [4].
*Tuomey, Prof. M., Tuscaloosa, Alabama [1].
Turnbull Lawrence, Philadelphia [10].
Turner, William W., Washington, D. C. [7].
Tuthill, Franklin, M. D., New York [8].
*Tyler, Rev. Edward R., New Haven, Connecticut [1].
Tyler, Ranson H., Fulton, New York [10].

V.

Vail, Prof. Hugh, Haverford, Pennsylvania [8].
Vancleve, John W., Dayton, Ohio [1].
Van Duzee, William S., M. D., Buffalo, New York [7].
Van Derpool, S. Oakley, Albany, New York [9].
Van Pelt, Wm., M. D., Williamsville, Erie Co., New York [7].
*Vanuxem, Lardner, Esq., Bristol, Pennsylvania [1].
Van Vleck, J. M., Middletown, Connecticut [9].
Vaughan, Daniel, Esq., Cincinnati, Ohio [5].
Vaux, William S., Esq., Philadelphia [1].
Verreau, H. A. B., Montreal, Canada [10].

W.

Wadsworth, James S., Esq., Genesee, New York [2].
Wagner, Tobias, Philadelphia [9].
Walker, Rev. Jas. B., Mansfield, Ohio [7].
Walker, Joseph, Oxford, New York [10].
*Walker, Sears C., Esq., Washington, D. C. [1].
*Walker, Hon. Timothy, Cincinnati, Ohio [4].
Walling, Henry F., Providence [9].
Walworth, Reuben H., Saratoga, New York [10].
Warder, Dr. J. A., Cincinnati, Ohio [4].
*Warren, Dr. John C., Boston [1].
Wayland, Dr. Francis P., Providence [9].
Wayne, Rev. Benjamin, New Orleans [10].
Webber, Dr. Samuel, Charlestown, New Hampshire [1].
*Webster, H. B., Esq., Albany [1].

*Webster, Dr. J. W., Cambridge, Massachusetts [1].
*Webster, M. H., Esq., Albany [1].
Webster, Nathan B., Portsmouth, Virginia [7].
Webster, William F., Providence [9].
Weed, Monroe, Esq., Wyoming, New York [6].
Weinland, D. F., Cambridge, Massachusetts [10].
Welch, John, Newark, New Jersey [10].
Wells, David A., New York [2].
Wells, Dr. Thomas, New Haven, Connecticut [4].
Wescott, Rev. Isaac, New York [8].
West, Charles E., Esq., Buffalo, New York [1].
Wetherell, Prof. L., Legrange, Kentucky [2].
Weyman, G. W., Esq., Pittsburgh, Pennsylvania [6].
Wheatland, Dr. Henry, Salem, Massachusetts [1].
Wheatley, Charles M., New York [1].
Whipple, J. E., Lansingburg, New York [10].
Whipple, W., Adrian, Michigan [7].
Whitcomb, Joseph M., Salem, New York [10].
White, Aaron, Cazenovia, New York [10].
White, Charles, Crawfordsville, Indiana [10].
White, Horace, Chicago, Illinois [10].
Whitney, Asa, Esq., Philadelphia [1].
Whitney, J. D., Esq., Northampton, Massachusetts [1].
Whittlesey, Charles, Cleveland, Ohio [1].
Wilder, Alexander, Albany [10].
Wilder, L., Esq., Hoosick Falls, New York [1].
Wilkes, Capt. Charles, U. S. N., Washington, D. C. [1].
Willard, Samuel, Lima, New York [10].
Williams, Dr. Abraham V., New York [9].
Williams, Prof. L. D., Meadville, Pennsylvania [6].
Williams, Dr. P. O., Watertown, St. Lawrence Co., N. Y. [6].
Williams, Samuel Wells, Canton, China [10].
Williams, W. F., Mosul, Turkey [10].
Wills, Frank, New York [9].
Wilson, Prof. Daniel, Toronto, Canada [10].
Winchell, Prof. Alexander, Ann Arbor, Michigan [3].
Winlock, Prof. Joseph, Cambridge, Massachusetts [5].
Winslow, John F., Troy, New York [10].

Winslow, C. F., Troy, New York [10].
Woodbridge, George A., Auburndale, Massachusetts [10].
*Woodbury, Hon. L., Portsmouth, New Hampshire [1].
Woolworth, Hon. S. B., Albany [10].
Worcester, Dr. Joseph E., Cambridge, Massachusetts [2].
Worthen, A. H., Warsaw, Illinois [10].
Wright, Charles, Wethersfield, Connecticut [10].
Wright, Chauncey, Cambridge, Massachusetts [9].
*Wright, Dr. John, Troy, New York [1].
Wurtz, Henry, Trenton, New Jersey [10].
Wyman, Prof. Jeffries, Cambridge, Massachusetts [10].
Wynne, Dr. James, Baltimore [8].
Wynne, Thomas H., Richmond, Virginia [8].

Y.

Yarnell, Prof. M., U. S. A. [8].
Youmans, E. L., Esq., Saratoga Springs, New York [6].
Young, Prof. Ira, Hanover, New Hampshire [7].

The above list contains seven hundred and eighty-four names, of which sixty-two are of deceased members.

MEMBERS ELECTED AT THE ALBANY MEETING.*

Allen, Jerome, Dubuque, Iowa.
Allen, Nathaniel T., West Newton, Mass.
Allen, R. L., Saratoga Springs, N. Y.
Ames, Bernice D., Fort Edward, N. Y.
Anderson, M. B., Rochester, N. Y.
Armour, A. H., Toronto, Canada.
Baldwin, F. H., Waverley, N. Y.
Barber, Edgar A., Albany.
*Barnston, Dr. James, Montreal, Can.
Beadle, E. R., Hartford, Conn.
Benedict, Erastus C., New York.
*Benedict, Dr. N. B., New Orleans.
Bennett, Joseph, Albany.
Bent, Silas, U. S. N., New York.
Binkerd, F. S., Germantown, Ohio.
*Blackie, Dr. G. S., Edinburgh, Scot.
Blake, J. R., Greensboro', Ga.
Bolton, James, Richmond, Va.
Bradford, G. W., Homer, N. Y.
*Brünnow, F., Ann Arbor, Mich.
Bulkley, John W., Brooklyn, N. Y.
Bullard, Edward F., Waterford, N. Y.
Butler, Thos. B., Norwalk, Conn.
Cameron, Daniel, Johnstown, N. Y.
Campbell, John, New York.
Cavert, M. P., Amsterdam, N. Y.
*Chadbourne, P. A., Williamstown, Mass.
Chamberlain, Frank, Albany.
*Chauvean, Pierre J. O., Montreal, Canada.
*Church, A. E., West Point, N. Y.
Clark, Lester M., Canandaigua, N. Y.
Cole, Seth B., Albany.
Comfort, H. F., Middletown, Conn.
Conger, A. B., Haverstown, N. Y.
Cooley, J. E., New York.
*Cooper, Dr. J. G., Orange, N. J.
Cottle, T. J., Woodstock, Canada.
Cox, Samuel H., New York.
Crandall, Pardon S., Troy, N. Y.
Crosby, Alpheus, Hanover, N. H.
Cruikshank, James, Albany.
Dakins, Francis E., Albany.
Davidson, Robert, New Brunswick, N. J.
*Davies, Charles, Fishkill Landing, N. Y.
Dawson, J. W., Montreal, Canada.
Delavan, Edward C., Albany.
Devol, Charles, Albany.
Dexter, George, Albany.
Dickinson, John W., Westfield, Mass.
*Diehl, Israel, Sacramento, Cal.
Doremus, R., Ogden, N. Y.
Downes, John, Washington, D. C.
Duffield, George, Detroit, Mich.
Duncan, Lucius C., New Orleans.
Dwinelle, William H., New York.
Dyer, David, Albany.
Edmundson, Thomas, Baltimore.
Edwards, Richard, Salem, Mass.
Elderhorst, William, Troy, N. Y.
Elliot, Ezekiel B., Boston.
Estes, D. C., Albany.
Fairfield, J. W., Hudson, N. Y.
Fellows, Joseph, Albany.
Field, Roswell, Greenfield, Mass.
Fisher, Mark, Trenton, N. J.
*Fisk, L. R., Ypsilanti, Mich.
Flanagan, J., Montreal, Canada.
Flint, Lyman D., Concord, N. H.
Foote, Elisha, Seneca Falls, N. Y.
Fowler, Asa, Concord, N. H.
Freeman, Samuel H., Albany.
Fristoe, E. P., Washington, D. C.
Frothingham, Washington, Albany.
Gardner, James S., Whitestown, N. Y.
*Garrigues, Dr. S. S., Philadelphia.

* Those marked with an asterisk paid the assessment, and signed the Constitution without being formally elected.

Gay, A. M., Charlestown, Mass.
Gifford, J. P. S., Albany.
Gillespie, W. M., Schenectady, N. Y.
Gilman, D. C., New Haven, Conn.
*Gladstone, T. H., London, Eng.
Glück, Isidor, New York.
Goodrich, Charles S., New York.
Goodwin, William F., Concord, N. H.
Green, Everett W., Madison, N. J.
Green, Horace, New York.
Greene, David B., New York.
Griffen, N. H., Williamstown, Mass.
Gruvern, Julius, New Haven, Conn.
*Gulick, John T., Williamstown, Mass.
Hadley, Amos, Concord, N. H.
Hale, Albert W., Albany.
Hall, Archibald, Montreal, Canada.
Ham, L. J., Williamsville, N. Y.
Hamlin, Augustus C., Bangor, Me.
Handy, Isaac W. K., Portsmouth, Va.
Harrequi, Jose Salazar, Minerra, Mexico.
Hathaway, Charles, Delhi, N. Y.
Headley, William S., Albany.
Heffron, Daniel S., Utica, N. Y.
Hext, G., Oxford, England.
Hicks, Levi I., Walworth, N. Y.
Hill, Nathaniel P., Providence.
Hingston, W. P., Montreal, Canada.
Hodgson, W. B., Savannah, Geo.
Homans, Sheppard, New York.
Hopkins, James G., Ogdensburg, N. Y.
Hopkins, T. O., Williamsville, N. Y.
Horan, E. J., Quebec, Canada.
Horton, C. V. R., Chaumont, N. Y.
Hungerford, Edward, Wolcottville, Ct.
Hyatt, James, New York.
Ingham, Albert C., Madison, Wis.
Ives, Thomas Pointer, Providence.
*James, Charles S., Lewisburg, Penn.
James, John, Alton, Ill.
Jennings, Needler, New Orleans.
Johnson, B. P., Albany.
Johnston, Christopher, Baltimore, Md.
Jones, Thomas Walter, Montreal, Can.
Joslin, Benjamin F., New York.
Kendall, Joshua, Meadville, Penn.
Kerr, W. C., Cambridge, Mass.
Lauderdale, John V., Cleveland, Ohio.
Lieber, Francis, Columbia, S. C.
*Loomis, J. R., Louisburg, Penn.
Lusher, Robert M., New Orleans.
*Machin, Thomas, Albany, N. Y.
*Macomber, D. O., Middletown, Conn.
*Mallet, J. W., Tuscaloosa, Ala.
Marcy, O., Wilbraham, Mass.
Marsh, James E., Roxbury, Mass.
*Maupin, S., Charlottesville, Va.
McCall, John, Utica, N. Y.
McCoy, Amasa, Albany.
McMahon, Matthew, Albany.
McNaughton, Peter, Albany.
Merrill, J. W., Concord, N. H.
Mitchell, Henry, Nantucket, Mass.
Morange, William D., Albany.
Morgan, Lewis H., Rochester, N. Y.
Morse, M. L., Dover, N. H.
Munger, George G., Rochester, N. Y.
Mussey, R. D., Cincinnati, Ohio.
Mussey, D., Albany.
*Newcomb, Wesley, Albany.
*Nichols, John A., New York.
Noble, Capt. London, England.
O'Callaghan, E. B., Albany.
*O'Leary, Charles, Emmetsburg, Md.
*Ormiston, William, Toronto, Canada.
Ormond, J. J., Tuscaloosa, Ala.
Osborn, H. S., Liberty, Va.
Osten, Sacken R. von., Washington, D. C.
Otis, George A., Jr., Springfield, Mass.
*Parker, W. H., Middlebury, Vt.
Patten, D., Concord, N. H.
Peirce, James M., Cambridge, Mass.
*Perry, M. C., New York.
Phelps, Philip, Jr., Hastings, N. Y.
Pierce, William M., Petersburg, Va.
Pigott, A. Snowden, Baltimore, Md.
Pitman, Benn, Cincinnati, Ohio.
Pleasants, Thomas S., Petersburg, Va.
Porter, Samuel D., Rochester, N. Y.
Priest, J. A., Homer, N. Y.
*Prince, W. R., Flushing, L. I.
Pruyn, Robert H., Albany.
Putnam, Frederic W., Salem, Mass.
Rankin, Robert G., New York.
Reid, D. B., London, Eng.
Rennie, Alexander N., Montreal, Can.
Reuben, Levi, New York.
Rice, W. H., Albany.
Ritchie, E. S., Boston.
Robertson, Thomas D., Rockford, Ill.
Rockwell, Alfred P., New Haven, Conn.
Rockwell, John A., Norwich, Conn.
Rogers, William F., Philadelphia.
Roome, Martin R., New York.
Ruger, Edward, Janesville, Wis.
Sanger, W. W., Albany.
Sargent, Rufus, Auburn, N. Y.
*Savage, Thomas S., Paes Christian, Miss.
Schnee, Alexander, Madison, Wis.
Sclater, Philip Lutley, Oxford, Eng.
Seropyan, Christopher, New Haven, Conn.
Sheldon, D. H., Racine, Wis.
Sheldon, D. S., Davenport, Iowa.
Sias, Solomon, Fort Edward, N. Y.
Skinner, George W., Little Falls, N. Y.
Smith, E. Peshine, Rochester, N. Y.

Smith, Metcalf J., M'Granville, N. Y.
Spear, C. V., Pittsfield, Mass.
Starr, William, Ceresco, Wis.
Stearns, Eben S., Albany.
Stearns, Josiah A., Boston.
Steele, Samuel, Albany.
Stewart, James, Delhi, N. Y.
Street, Alfred B., Albany.
Sturtevant, J. M., Jacksonville, Ill.
*Swallow, G. C., Columbia, Wis.
Sweeney, Peter, Buffalo, N. Y.
*Tappan, H. P., Ann Arbor, Mich.
Tatlock, John, Williamstown, Mass.
Tatum, Joel Haywood, Baltimore, Md.
Taylor, George W., Albany.
Taylor, J. W., Wampsville, N. Y.
Thomas, William A., Irvington, N. Y.
Thompson, John A., Cayuga, N. Y.
Thorn, James, Troy, N. Y.
Townsend, Howard, Albany.
Treadwell, O. W., Rockville, Md.
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Truesdell, Samuel, New York.
Turnbull, Lawrence, Philadelphia.
Tyler, Ransom H., Fulton, N. Y.
Upham, N. G., Concord, N. H.
Vail, S. M., Concord N. H.
*Verreau, A. B., Montreal, Can.
Walker, Joseph, Oxford, N. Y.
Walworth, R. H., Saratoga, N. Y.
Wayne, Benjamin, New Orleans.
Weinland, D. F., Cambridge, Mass.
Welch, John, Newark, N. J.
Weyde, Vander, New York.
Whipple, A. B., Nantucket, Mass.
Whipple, J. E., Lansingburg, N. Y.
Whitcomb, Joseph M., Salem, N. Y.
White, Aaron, Cazenovia, N. Y.
White, Charles, Crawfordsville, Ind.
White, Horace, Chicago, Ill.
Wilder, Alexander, Albany.
Willard, Samuel D., Lima, N. Y.
Williams, Samuel Wells, Canton, China.
Williams, W. F., Mosul, Turkey.
Wilson, Daniel, Toronto, Canada.
Winslow, C. F., Troy, N. Y.
Winslow, John F., Troy, N. Y.
Wood, William, Portland, Maine.
Woodbridge, George A., Auburndale, Mass.
Woolworth, S. B., Albany.
Worthen, A. H., Warsaw, Ill.
Wright, Charles, Wethersfield, Conn.
Wurtz, Henry, Trenton, N. J.
Wyman, Jeffries, Cambridge, Mass.
Zimmerman, Reuben, Alexander, Va.

The following signed the Constitution, but were not formally elected and did not pay.

Beumard, Daniel, Chicago, Ill.
Forsyth, James, Troy, N. Y.
Homes, H. A., Albany, (State Library).
Hooper, C. Van Vorst, New York.
Lane, D., Troy, N. Y.
MacNair, John, New Orleans.
Mayhew, D. P., Ypsilanti, Mich.
Mütter, Thomas D., Philadelphia.
Sanders, J. Milton, Cincinnati.
Sprague, Joseph W., Rochester, N. Y.

The following paid, but were not formally chosen, and did not sign the Constitution.

Army, W. F., Chicago, Ill.
Freeman, L. H., Albany.
McClure, A.
Paine, D. D.
Pendleson, E. B.
Wilson, J. Q.
Thompson, Robert.
Wendell, Dr. H., Albany.

REPORT

ON THE PRESENT STATE OF OUR KNOWLEDGE

OF

LINGUISTIC ETHNOLOGY.

By S. S. HALDEMAN, Columbia, Pa.

This Report will be restricted to the portion of the subject pertaining to speech,—a portion which, although less extensive than the grammatical, lexicographical, or etymological portions of language, has not attracted proper attention until a recent period. This neglect is due to the difficulty of the subject, of which a constant example is at hand in the difficulty experienced in pronouncing foreign languages properly, even when they belong to the same stock, as Persian, German, Belgian, and English. The difficulty of pronouncing, appreciating, locating, explaining, and writing down the various phases of speech is so great, and there are so many sources of error, that we must be more cautious in accepting statements here, than in other sciences of observation, few having as much education in this branch as would be required to make a chemist or a musician; or to enable a singer to write down a song properly, even in a notation of his own invention. We cannot even trust an observer who claims for himself a good ear. The English lexicographer, Knowles, makes such a claim, and by his analysis proves that he does not possess the power to discriminate sounds; as in the case of *ye* and *woo*, which he considers equivalent to the repetitions *e-e* and *oo-oo*. The re-

porter is willing that the objections which he makes to the results of others should be urged against his own; and that his assertions should be received with as much caution as those of any observer, having at various times held views which further research proved to be untenable.

Spanish grammarians emphatically deny that their *b* ever partakes of the power of English and Spanish *v*. They claim both *b* and *v*, and assert that *v* (like *f*) is made by the application of the lower lip to the upper teeth, and that their *b* is never made thus, the lips alone being concerned in its production, so that it is impossible that it can be anything else than a genuine *b*. The facts are as here given, but the inference is false. The Spanish *b* between vowels, the German *w*, and, according to E. A. Sophocles, the Ellenic* *β*, differ from English *v* in being formed with the lips alone. It is therefore an aspirate of *b* (*B*) as the Greek *φ* is an aspirate of *p*, which *f* is not. This is an important point in ethnology, which few attend to. Doctor Lepsius does not allude to it, nor to the very distinct Russian vowel bl, in his recently published Standard Alphabet. Authors continually confound English labio-dental *v* with German labial *w*, and in giving an account of the languages they investigate, they cannot be trusted upon this point; so that we have yet to learn which of the two sounds is present in certain languages, the phonology of which is apparently treated with great fulness. Judging from a partial investigation, the Russian 'B' has the power of English and French labio-dental *v*.

Some writers (as Le Brethon and Marsden), in comparing the French and English vowels, refer â to that in *fall*, and é to

* *Modern Greek* is an awkward expression, and *Romaic* is incorrect, and as the language has lost *h*, *Hellenic* has become *Ellenic*. The word *Anglo-Saxon* is equally awkward, and degenerates into "*Saxon*," — a name which should be restricted to *Plattdeutsch* in its modern and ancient or old Saxon form. The change of languages involves a change of pronunciation, as in the German *klar*, which closes to *clair* in French, and still farther to *clear* in English; so the language of Anglia and the Angles was *Anglish*, and passed through *English*, with *e* in *met*, to the modern *Inglish*, with the vowel in *fit*.

that in *end;* whilst others (Picot, Bolmar, &c.) refer â to the English vowel in *arm*, and é to that in *fate*. Duponceau, in 1817 (Am. Phil. Trans. I. 229), refers the English vowel in *fat* to the French vowel in *terre, père*, an error which Germans commonly make. In the alphabet of Lepsius, *fat* would be written fæt, and the French *mère* mēr. Duponceau seems to have been the first to show that the initial vowel of the English diphthongs in *aisle* or *isle*, and *owl*, is not that in *arm*, but the French â, which is made with a narrower aperture than *a* in *arm* requires, and with a slight tendency towards *awe*. The same author gives as the components of English *u* in *usage*, the vowels of *eel* and *ooze*, — an error which is retained by most English authors, very few of whom know what a diphthong is.

Every vowel added to a word forms an additional syllable, and as English *u* is a monosyllable, one of its elements is a consonant; namely, the initial when it is pronounced *you*, and the final when, as is sometimes the case, it is a diphthong pronounced like the Welsh *iw* and Belgian *iew*, with the vowel of *it* (German *hitzig*) and *w* as a consonant in *now*, or German *u* in *haus*. Similarly, the final element of *clo-y* is a consonant, and of *claw-y* a vowel.* German and French writers seem not to be aware of the nature of diphthongs, and in Latin-English grammars they are described as vowels.† In most ethnic alphabets, including that of Lepsius, the last element of the diphthongs is represented by a vowel character, — a fundamental error founded upon the crude analysis of the ancients.‡ The term *diphthong* is itself almost useless, because,

* Hald. Latin Pronunciation, §§ 109, 111. Latham's English Language, 1841, p. 108, § 68.

† Andrews and Stoddard consider the vowels of *fall* and *feel* diphthongs, because they pronounce the Latin LAVS and AETAS with them. They say that "two *vowels* in immediate succession in the same syllable" (including UO, UA!) "are *called* a diphthong. Yet if AETAS is read with but four elements instead of five (the *a* in *arm* being omitted), the word does not contain "two vowels in immediate succession."

‡ Dr. Lepsius assigns (Standard Alphabet, p. 41) to the Latin *diphthong* OE (*oi* in *going*, when pronounced as a monosyllable) the power of the German *vowel* ö, and'

as the first element is already a vowel, the peculiarity lies in the second coalescing with the first, (an impossibility with a second and subsequent vowel,) whence it may be called a *coalescent*, meaning by this term those consonants that approximate as nearly as possible to the vowels.

In a French work on Russian, the twenty-ninth Russian letter, b, is explained by comparing it with the French "e mute," whilst the twenty-seventh letter is said to have no sound, but to indicate that the preceding consonant is to be pronounced with force, and as if it were doubled. This gives a very incorrect view of these letters. For example, the Russian word for *five* is a monosyllable with the short *a* in *art*, which might be represented pjatj in Latin or German letters, and pyaty in English letters, the final *y* being the Russian (b), and the modified y-sound following *l* in the French "ll mouillée." This addition to consonants is so common in Russian, that its absence is marked by the *yerr*, as in the word o-ke-án *ocean*, which is written with the final *yerr*. The allusion to doubled letters might cause Russian to be associated with Arabic, Latin, and Italian, which are among the few languages which have doubled or geminate elements, as in the Italian "Giovanni," *John*, in which each *n* is as distinctly sounded as in the English words *one name*.

Arabic has such doubled consonant sounds; yet it would be wrong to consider the sixteenth Arabic letter *tta* such a gemination on the authority of Richardson, who describes it (Grammar, p. 9) as "double *t*, or *t* with a slight aspiration," a description which is void of meaning, the reader being unable to tell whether the conjunction is copulative or disjunctive, and consequently whether the latter member of the sentence is explanatory of the former. Brown (Journey to Dar Fûr) assigns to the Dar Runga, words like *tta* water, *mmi* wo-

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ignoring the Latin nasal vowels, writes *kǫlum* for COELUM. The dots are placed below ö to afford room above for accent marks, yet nasal vowels are indicated by (˜) above, which may call for vowel characters surmounted with the three signs (˜ ˘ ˇ). Thus the French word *sans* (sa˜) is long, and *cent* (sa˜) is short.

man, *ddéta* mountain, *wwi* wind, *ggó* reprimanding; but as he gives no explanation of his notation, these are doubtful examples of geminate consonants.

Many English people fancy that they have double consonants, because they spell certain words (e. g. all, well, off, lesson, back, annex, allude) with double characters. This practice is in use to indicate a short preceding vowel, and when an Englishman writes a Latin Grammar, he is apt to believe and assert that syllables which are long "by position" are really short, but are "counted" or "considered" long, by a "mechanical rule"; whereas, the doubled consonants heard in Italian show that such syllables are really long, because it requires more time to pronounce two elements than one.* Similarly, Latin diphthongs are long, not by an arbitrary rule, but because the two elements of AV, AE, OE, &c. require more time than A and O alone.

The nasal vowels of but few foreign languages are properly understood, and the ignorance of writers whose vernacular does not contain them is frequently apparent. The error here is sometimes so great, as to cause a confusion between vowel and consonant, as in mistaking the nasal vowel of the French *in* for the English and German *ng* in *fang*. The French word *fin* contains but two elements, a consonant followed by a genuine vowel, whilst the English *fang* has three elements, and ends with a consonant. The mistaking one for the other would be exactly paralleled in the practice of a foreigner who for *pea* would give *peag* as an English word.

This error in regard to the nasals appears in Riggs's valuable Grammar and Dictionary of the Dacota Language, based upon the studies of a number of observers during a period of eighteen years, and submitted to the inspection of a learned committee previous to its publication by the Smithsonian Institution. To a given character the power of 'n' in the French

* Most English grammarians do not distinguish between the length and the quality of their own vowels, regarding *a* and *o* in fāte and ōbēy as long, and those of făt and ŏbjĕct as short, although, in these examples, the quantity does not differ.

bon and English *drink* is assigned, so that the reader is unable to pronounce with certainty the numerous words represented by this character, — an 'n' the second line of which is produced and ends like 'j.' But it is probable that neither the French nor the English sound occurs uniformly, for in the allied Conzo (each *o* as in *not*, *z* in *zeal*) the reporter has heard both, as (to use German characters) in hüng-ga *leggins*, with *ü* long and accented, and *a* short as in *art*. The French sound occurs in the Conzo word for *five*, which is the English syllable *saw* accented and followed by *t* and the French *un*, as if sàwtŭⁿ. Using '*n*' for Mr. Riggs's letter, the Dacota word for *leggins* is hunská, and for *five*, zaptan.

Independently of the errors of observation, some writers have a practice of referring the sounds they meet with to those of other languages which they may know from description alone; and some proposers of general alphabets supply such foreign sounds with characters, although they run the risk of giving different characters to the same sound, or of confounding distinct sounds. An English alphabet-maker, upon reading that the Lenape (lenāpɛ) aborigines use a whistle in speech, might propose a character for it, although this sound is nothing but English *wh* before a consonant, as in whtē *heart* (*e* in *they*), its occurrence in a new connection conveying an impression analogous to that which a new sound would give. In comparisons of sounds, the reader should be informed whether the author has heard those he uses for comparison, and whether his opportunities have been few or many. Some sounds can be accurately described to those unfamiliar with them, as the German *w*, Greek *phi*, English *th* in *thin*, *then*, Welsh aspirate *ll*, *rh*, which latter, together with the Oriental *ghain* and its surd cognate (as they occur in Armenian) the reporter was accustomed to pronounce before he heard them from natives.

The alphabets used by various authors will give a good idea of the state of our knowledge in this department, except that they will not always enable us to establish a parallel between

them. After Rapp's Physiologie der Sprache, the Essentials of Phonetics of Mr. A. J. Ellis, A. B., London, 1848, may be placed, as a conscientious and valuable contribution to the general subject. Being printed in the author's alphabet, its use is restricted to those who can speak English. The alphabetic portion of this treatise is so corrupt, that it ought not to be used for any language; but it has an important concession to correct scholarship, in the use of Cay (and not Kah) as the cognate of Gay.

Castrén's Grammatik der Samojedischen Sprachen (St. Petersburg, 1854) contains a careful analysis of the sounds used. The iotacized (mouillées) consonants, or those followed, and in some cases modified, by the guttural coalescent approaching English y in *million*, are seven in number, *l*, *r*, *n*, *t*, *d*, *s*, and English *z*, marked with a curved line through the stem (on the right of *n*, *d*) of the characters, — an awkward notation requiring too many distinct characters. Ellis uses (j) deprived of its upper and lower dot (as in lj,) which is unexceptionable. The peculiarity of these compounds is, that whilst they commence with *l*, &c., the tongue passes to the iotacism before the *l* is completed, *million* being mil$^{l}_{j}$yon when thus iotacized, which, however, is not essential to its purity as an English word. A soft lisped *d* is assigned to Lappish, which is allied to a lisped *r*. The latter quality seems to remove it from English sonant *th* in *then*. This curious sound should be compared with the peculiar Irish *l*, which the reporter first noted as an l-sound mixed with sonant *th*, but subsequently determined to be the sonant analogue of the Welsh surd aspirate *ll*, to which it would bear the same relation that *thy* bears to *thigh*. A sound between *f* and *h* is mentioned, — probably Greek *phi*; and a consonant between *l* and *r*. Castrén assigns a peculiar u̯ to Ostiak, and the Russian vowel bl to Samoiede. The latter (which has been heard by the reporter) may be described as a long and short vowel akin to English and German *i* in *still*,* but formed with a more open aperture, and the an-

* This is not the short quantity of the vowel in *field*, and cannot be correctly represented by (ĭ) of the Latin and Italian alphabets.

gles of the lips drawn back. It has the pinched quality of German ö and ü, but without the pursed lips used in forming these well-known vowels.

Böhtlingk (Ueber die Sprache der Jakuten, St. Petersburg, 1851) mentions a nasal of the German J. The reporter* mentions such a sound as present in Wyandot, and a close of the glottis (marked ⊱) which has since been observed in Chippeway. Judging from information received from a European who had resided in Syria, this "close of the glottis" is the Arabic effect termed "spiritus lenis" and marked (') by Lepsius.

S^{v}uñić (in German letters Schunjitsch, an Illyrian), De Vera Orthographia, cum Necessariis Elementis Alphabeti Universalis, (Viennæ, 1853,) admits twelve vowels, which, with marks of accent and length, require seventy-two modifications of vowel characters. He supposes that these twelve correspond with the twelve semitones of the musical scale, a view which is fundamentally erroneous. Of the consonants he enumerates fifty, including the mouillé kind, and a few like *ts*, *tsh*, &c. He assigns to the German *w* the power of the English *w*, and considers German *b* in *haben* different from the ordinary *b*, his informant having probably been a provincial. He omits English and German *ng*, or confounds it with the French nasal vowels; and his notation is over-crowded with diacritcal marks.

Poklukar (probably an Illyrian) published a pamphlet at Laibach in 1851, entitled, Ankündigung eines nächst zu veröffentlichenden allgemeinen lateinisch-slavischen, zugleich deutschen, französischen, italienischen und eventuel auch eines Universal- oder Welt- Alphabetes, &c. He confounds German *ng* in *lang* (Eng. *long*) with French *n* in *loin;* and French *v* with German *w*. His notation is objectionable, although he starts with the best possible rule to secure correctness and final

* On some Points of Linguistic Ethnology; with Illustrations, chiefly from the Aboriginal Languages of North America. Proceedings of the American Academy. Cambridge and Boston. October 2, 1849. 8vo.

uniformity, by preventing each author from being influenced by the power which a letter may happen to have in the alphabet he is best acquainted with. This rule requires that *an alphabet should not contradict the Latin original*, Latin being in some sense the (Weltsprache) universal language. The reporter's Elements of Latin Pronunciation (Philadelphia, 1851) grew out of a perception that, without such an investigation, not a single step could be made in the right direction towards a general alphabet, the construction of which should be based rather upon scientific principles than upon the vagaries of each individual who may be called upon to write a language for the first time. Poklukar uses B, F, J, and other letters, correctly, but by a false assumption he uses C as *ts* (although he had already a *t* and an *s* in his alphabet!) and prefers *x* to the Latin Cay or Greek Kappa.

Among the latest works upon the subject* is Professor Lepsius's Allgemeine linguistische Alphabet, (Berlin, 1855,) of which there is an English version, entitled, "Standard Alphabet for reducing Unwritten Languages and foreign graphic Systems to a uniform Orthography in European Letters, &c." (London, 1855.) The profound learning of the author, and the use he has made of his alphabet in the languages of Nubia and Dar Fûr, render this a very important work. It has been approved by the Royal Academy of Berlin, which has had the necessary types cut to give the system publicity; and many of the missionary societies have adopted it, including the English "Church Missionary Society," who have commenced using it in the works of the Rev. S. W. Kölle on the languages of West Africa. Professor Lepsius expresses a hope, that, in cases where missionaries are disposed to make alterations in his notation, "the Committees of Societies will require the reasons of such deviations to be laid before them and discussed."

* Lauth's Vollständige Universal-Alphabet, (München, 1855,) and Professor Max Müller's Languages of the Seat of War in the East ..... with an Appendix on the Missionary Alphabet, — have not yet been received.

This system professes to have a physiological basis, and the labors of the eminent physiologist, Joh. Müller, are acknowledged in this field. Mr. Ellis states that, in Müller's account of the elements, "the faults of a German ear are still conspicuous." Müller (Elements of Physiology, English edition, 1848, p. 1051) does not understand the nature of his own J, which he supposes a sonant German *ch*, as English *z* is a sonant *s*. With him, *m* is not a labial consonant, and he does not know the distinction between *p* and *b*. He considers *p* as having an aspirate quality, probably because an aspirate is made after it, as in pronouncing *tap'*, where a Chinese would say tap'. If *p* in *tap'* and *haphazard* is to be named an *aspirate* from the phase which follows it, the *p* in *pay*, *play* must be a vowel, or the consonant *l*. If the *t* in *boathook* is an aspirate because *h* follows it, it is equally an aspirate when it precedes, as in the Iroquois word ă'htă.

Professor Lepsius says that in *adna* or *anda* we pronounce "only half the *n* and half the *d*, whilst in *ana* and *ada* we pronounce the whole of *n* and *d*." According to this reasoning, as *n* cuts off the first half of *d* in *anda*, and the last half in *adna*, both halves of the consonant between consonants must be lost in *lend not*, *wends*, *endless*, *string*, *warps*, and in the German proper names *Heindl*, *Jöndl*, *Zarbl*, *Birkl*, *Schmölzl*, *Dietzsch*, &c.

This mode of regarding a consonant position and a vowel position of the organs as in a manner constituting a unitary element, has given rise to alphabets of a more or less syllabic character, like the Cherokee, Ethiopic, Hebrew, and Sanscrit; and the system of Professor Lepsius is heterogeneous in admitting *t* and *a* for *ta*, whilst in the Hottentot dental* clack he uses but one character for the *consonant* position of the organs (a kind of *t*), and the reverberation which follows it in the cavity of the mouth, set in a *vowel* position.

* Mentioned here because it is the only one heard from a native by the reporter, who has, however, heard several others in American languages. A change of notation is required to distinguish the clacks formed by sucking in air from those in which it is expelled.

Professor Lepsius considers the vowel in *worth* as "inherent in all soft fricative consonants," such as English *v*, in which there is indeed sonancy, but no vowel power, and least of all one requiring such open organs as that in *worth*. If anything, the supposed inherent vowel in English *v* is German ü.

A consonant like *l*, *r*, and English *z*, may have the organs so little closed as to approach the vowel quality, and in this case the small circle placed beneath the character by Dr. Lepsius is a good mark. But he uses the mark with *n* and *m* when they form syllables, although in these cases they do not differ from ordinary *m*, *n*. Thus if *z*, in the Chinese word *tsz* quoted by him, is English *z* following *s*, it does not want the mark. In English, the second vowel of *misses*, *horses*, is often omitted in hurried or careless speech, forming the dissyllables *mi-sz*, *hor-sz*, as in *su-dn* (sudden), *pri-sm* (in which *sm* have the same power as in pri-smat-ic), German *v'r-la-ss'n*, *v'r-der-b'n*. In rare cases a mark of syllabication will be necessary, as in *prairie*, often pronounced in English as a trisyllable, with or *without* the vowel of *utter* in the first syllable, in the latter case forming *pr-ai-rie*.

Professor Lepsius follows the English in admitting an "indistinct vowel sound" in nation, velvet, &c. This is the vowel of wŏrth and ŭrn, which stands on the throat side of the vowel scale, opposite to *awe* on the labial side. It does not yield in distinctness to any of the vowels, but as Latin U and V (English *w*) and I and J are allied, so the vowel in *urn* approximates English smooth *r*, and coalesces with it. Hence, if a person pronounces *ramrod* (ra-mrod), omitting -od, the listener accepts the remainder ra-mr as *rammer*. This so-called "indistinct vowel" is doubtful as a German sound, being more probably elided in *lieb'n*, &c., as it sometimes is in the English words *nation*, *theatr'*, &c. Its resonance may, we are told, be lost "by partially contracting the mouth, or even closing it entirely. In the latter case it is heard through the nose." This supposed vowel is the consonant *m*. The English vowel *awe* is given as an Italian sound, although this lies between *awe*

and *owe* (Ellis, p. 20). But six labial consonants are admitted, *p*, *b*, *m*, *f*, and English *v* and *w*, no mention being made of *ϕ*, Ellenic *β*, nor English *wh*, although English examples are freely cited, and the number of English consonants stated to be twenty-two. English *wh** was probably supposed to be English *w* (Latin v in QVINQVE, SVAVIS, &c.) preceded by *h*, an opinion in which Professor Lepsius was likely to be seconded by the English committee which he met, and this view would probably be sustained by the missionary committees to whose decision he would have the results of original investigators referred, in case they should differ from the views laid down in the Standard Alphabet.

If such grave errors can take place with the labials, the organs of which can be *seen* and *felt*, in addition to the sounds being *heard*, we may well doubt the analysis of sounds formed out of sight, in the depths of the fauces; and consequently, the following observations are open to correction. Recalling the admission that the reporter has never heard Arabic from a native, yet he is vernacularly familiar with the German smooth aspirate or spirant of *gay* in *re'gen*, which is the sonant of *ch* in *ich*, is free from vibration, and belongs to the *cay* contact. The Ellenic *gamma (judged by ear from native sources) belongs to the same contact, is made with a similar close of the organs, but has the addition of a mild vibration, probably due to the vibrant action of the *edge*, and not the body, of the palatal veil. The French *r* grasseyée is probably formed by the *body* of the palatal veil, with perhaps little or no contact of the tongue and palate, wherein it would differ from *gamma.

Some of the Oriental languages have a contact behind that of *cay*, of which *qof* may be considered the characteristic. Aspirating *qof* produces a faucal *qh* analogous to *χ*, and when this is made sonant the analogy is with aspirate *gay*. Professor Lepsius considers the German aspirate *g*, Ellenic *γ*, and

* In a former paper, the present reporter has affirmed that no orthoepist known to him had been able to state correctly the elements which occur in the English word *when*.

Armenian *ghad* identical, and of course represents them with the same character; and the surd form of *ghad* is considered identical with *ch* in *ich*, — a greater error, apparently, than to confound *cay* and *qof*, or the Arabic "spiritus lenis" (') of Lepsius, with ;ain, as he marks it.

Richardson, in his Arabic Dictionary, says of *ghain*: "This letter is articulated in the throat with a *vibration* producing a sound like that given to *r* by the Northumbrians, or the noise made in *gargling*. . . . It seems to bear the same relation to *kh* as *b* to *p*," — i. e. the relation of sonant to surd. The *kh*, he states, "is generated by a gentle *vibration* in the throat"; consequently it is not the Greek nor German *chi*. Sir William Jones says that "the Persians and Arabs pronounce their *ghain* with a burr in the throat and a tremulous motion of the tongue, as in making the rough *r*"; — and according to S'uñić its surd analogue is an aspirate "qui a graeco χ *chi* in eo differt quod quasi gargarizando efferatur."

These two vibrant sounds appear in the following Armenian words, premising that, as the character for the Armenian *ghad* resembles an angular "2," this will be used for it, whilst ʿq will represent the surd sound; ə the vowel in *under*, ɛ that in *met*; ʌ that in *arm*, but short in these examples; ſ English *sh*; c as *k*; and the objectionable character z as in English: —

DZNDZ2Ăʹ, *a cymbal*; ʿQɛLC, *the mind*; ʿQĂTſ, *a crucifix*; ʿQə́ʿQəNTſɛL, *a neigh*.

The division of the consonants into contacts is natural, and was appreciated by Aristotle, the Hebrew Grammarians, the Abbé Sicard, &c. A consonant character indicates a closing of the organs, as *p*, *t*, *f*, whether it precedes another effect, as in *fay*, *play*; or follows, as in *off*, or does both, as in *eft*. Each contact is subject to nearly the same phases, that is, if the closed lips make *p*, the tongue will make *t* and its base *k*. Adding sonancy to these gives *b*, *d*, *gay*; open the nasal passage, and these become *m*, *n*, *ng*. Professor Lepsius divides the phases of the contacts into *explosivæ* or *dividuæ*, as *t*, *d*,

n; *fricativæ* or *continuæ*, as *s*, *z*; and *ancipites*, as *r*, *l*. In the labial contact, *p*, *b*, *m* are placed as explosives; *f*, *v*, *w*, (English) as fricatives, without any ancipites; although English *w* is to *b* as *l* is to *d*, and English *y* to *gay*. Apparently to accommodate the German nomenclature, voiceless consonants, as *p*, *f*, are termed *fortis* instead of *surd*, whilst *b* and English *v* are termed *lenis* instead of *sonant*. The fricatives are the aspirates of other authors, whether sonant or surd, except with those who think "sonant aspirate" contradictory, and prefer "spirant" for such elements as English *v*, *z*, and *th* in *then*.

English *w* and *y* (Latin V, J) are *not* fricative in the sense of *f*, *s*, *χ*, &c., but they become so when aspirated in the words *when* and *hue* or *hew*, the initial of which is in neither case *h*, as many suppose. Writing *hue* in Latin letters and marking surd by (') it will stand 'JJU or JhJU, English *u* being normally Latin JU.

Instead of twenty-two "simple consonantal sounds" assigned to English by Professor Lepsius, the following may be enumerated: —

Labial.	Dental.	Palatal.		Guttural.	Glottal.
w	l	r	soldier	y	...
wh	...	...	nature	hue	h
m	n	...	...	ng	...
b	d	...	...	g	...
... v	dh ...	z	zh	...	...
p	t	...	...	k	...
... f	th ...	s	sh	...	...

To these twenty-six might be added an *r* (as some English people use both a rough and a smooth one), and *mh* for the English and German exclamation *hm* (really 'mm), a surd aspirate followed by pure *m*. This aspirate is sometimes replaced by '*n* (found in Cherokee) and '*ng*. See Rapp, Vol. II., middle of p. 267, and Vol. I. p. 166, note.

It is here intended to assign to the English word *nature* a

surd, and to *soldier* a sonant effect, allied to *y* in *ye*, *you*, but made at the post-palatal point, and constituting the liquids of which *zh* and *sh* are the aspirate mutes, and into which they are apt to fall, just as *r* may fall into *s* or *z*, or *w* into *v* or *f*. Hence *nature* is often natsh'r, as *soldier* is soldzh'r. In the mouillé effect, the modified *y* is not only drawn forward to the palatal position, but when it follows a dental, this often recedes to meet it, even when the double effect has become t-sh, that is to say, in order to bring *t* nearer to *y*, or to *sh*, it is often drawn back from the teeth, and the point placed against the base of the lower teeth as a fulcrum.*

The notation of the "Standard Alphabet" is defective, whilst tendencies towards uniformity are not fostered by its third and fourth rules, which do not regard the purpose for which a given character was invented. The four rules are:—

I. Every simple sound ought to be represented by a simple sign.

II. Different sounds are not to be expressed by one and the same sign.

III. Those European characters which have a different value in the principal European alphabets, are not to be admitted into a general alphabet.

IV. Explosive letters are not to be used to express fricative sounds, and *vice versa*.

The first two rules are proper, the others are exceptionable. The first is broken by its proposer in assigning a simple character for the contact and the subsequent resonance of the Hottentot clacks. The second is broken by representing the English combination *t-sh* partly by *t* and the character for *sh* (p. 55), and partly (as in Arabic and Persian) by *k* surmount-

* When the iotacism follows a labial or guttural, it can scarcely be called a mouillé effect, although it is so considered in the Slavonic languages. The *t* and *d* thus drawn back to a slight extent in the English t-sh and d-zh, would require little to place them among the palatals, when the *t* would be the lenis of *s*, and the *d* of *z*, or, if nasalized, it would form a sound between *n* and *ng*, perhaps the Sanscrit palatal ña.

ed by an accentual. In Mpongwe (p. 57) this *k'* stands for English *ty*, and on p. 42 *t'* is assigned to *ty* in case it should be required. Hence, in his alphabets of Kúa and Hererб (p. 57) we do not know whether *k'* means *tsh*, *ty*, or even *ky*.

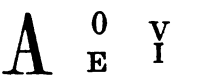
By Rule III. *c*, *ch*, *j*, *x*, are excluded, and most of the characters might have been got rid of by the same unphilosophical process. If in the course of time the measures of the French metre should become shortened, partly by the abrasion incident to use, and partly by the file of avaricious dealers, whilst other dealers, with a higher appreciation of strict accuracy, would preserve their measures at the standard value, — if, under such circumstances, the government were to enforce uniformity, those who had allowed their standard to deteriorate would be clamorous for the retention of their own, as the best known. Strict justice would require that the original metre should be restored, although none but a few just traders might have it in use.

Notwithstanding the nations of Europe have faithfully preserved the vowel characters, even to the y (German ü) of the Danes and Swedes,* there are several alphabets of English origin, which (simulating the weights and measures of certain dealers) fall so far short of the standard that every vowel character, even to that of O, has false powers assigned to it, the opinions and practice of those being disregarded who had for ages kept their standard pure.† No sophistry should induce a Danish missionary to pervert a letter (Y) belonging to, and made for, a *labial vowel*, to the power of a *guttural consonant*. Philologically, it is worse than assigning to Latin, German, Polish, &c. J, the power of English *w*. Let Latin 'V' have its vowel power in *ooze*, 'I' that in *believe*, and 'Y' that of the French *pinched u* (which bears equal relations to this V

* Besides the correct use of Y, the orthography of the Danish word "havn," a haven, (rhyming with *town*,) is strictly Latin.

† Some English authors have gone so far as to assign to Anglish *cay* the power of tsh, as if to flatter superficial readers with a greater resemblance to English. Were this view true, the English words broken, kernel, ache, and kin, would be older than the Anglish brocen, cirnel, ece, and cynn, Irish cine.

and I), when we may account for the form of 'Y' by the following diagram of the affinities of the vowels:—



The rule which rejects C should not retain its cognate G, and that which assigns to the latter its original, standard power in *get, give*, should have retained C (or at least a character like *k* deprived of its stem) with its Latin, Gaelic, Welsh, and Anglish power, as Mr. Ellis has done. 'C' (aided by 'Q') is the *normal character* for *cay* in the Romanic languages; and the Latin, German, &c. *ch* is a concession that, if '*ch*' represents the aspirate χ, 'C' without the aspirate mark *h* must normally represent its lenis form *cay*. 'C' is rejected by Rule III., on account of its many perversions, although still used *correctly* in several languages, whilst 'Z,' with as many perversions, is improperly retained with a *corrupt* power. Its powers are as follows:—1. Ancient Greek, as English *zd;* 2. Italian *dz* (and *ts*); 3. German *ts;* 4. English in *azure;* 5. As *s* in Hungarian and Danish, and the German '*tz*'; 6. Its French power; 7. Its Spanish power.

The normal character for the sonant *s* in *rose, misery*, is *s*, in German, French, Italian, and English; and as the Latin mode of distinguishing sonant from surd is seen in G, C, the sonant '*s*' should have ended in some similar manner, as by a comma point. In writing, this would degenerate into something like the numeral sign '3,' a form which is used in Russian for English *z*, constituting a very suitable letter. Nevertheless, the adaptability of a Z rounded into a reversed S should be considered.

As English *sh* belongs to a different contact from *s*, it should not be represented by a pointed '*s*,' nor French *j* by a pointed '*z*,' such a mode being as unphilosophical as to represent χ by a pointed *sh*, or *th* by a pointed *f*. The character ſ (but not *ſ* with its dot and curve below to be written with the stem of script *l* and the tail of *y*, like the German script *h*) was

proposed by Volney for *sh*, and has been used to some extent. For French *j*, the Wallachian form is probably the best, being somewhat like (ʃ) inverted 'f,' with a curved line through the stem, sloped in the direction of the acute accentual. Some such characters are necessary, the paucity of aspirate consonant characters in the Roman alphabet being admitted.

Rule IV. is probably based upon forms like 'th' for the Greek theta, — a false notation for this sound, because theta is not an aspirate of *t*, but a member of a different contact, so that to render theta lenis ('θ) it would be a kind of *t* formed between the teeth; and truly to aspirate *t* ('t) would be to form a sound strictly at the *t* contact, with a quality between the aspirates θ and *s*. Similarly, 's would be *s* deprived of aspiration, forming a kind of *t* posterior to the normal *t*.

The use made by Dr. Lepsius of (θ) for the surd consonant of *thigh* is unexceptionable, but as he wants a character for the sonant of *thy*,* he wavers between θ̈ and δ, proposing at the same time θ̈ for θ; thus establishing a complete confusion in the use of the Greek spiritus asper and lenis marks. In θ̈ an aspirate mark is added to that which is already aspirate, that *surd* may be understood; and in θ̈ the lenis mark indicates that *vocality* has been added, not to θ̈, but to an imaginary θ. In h' the aspiration of the Arabic *hha* is enforced, although the Ethiopic character (ሐ) was present in an inverted Greek Ψ-character, which would recall the European idea of *hh*. The (χ) with postposited (') is given for Arabic *ghain* and Ellenic *gamma*, although (χ') ought to mean *k*. In this notation (f') would mean *f*; (f') English *v*; † and (s') English *z*.

* That of Mr. Ellis formed on a (d) basis is probably the best, — or rather its later form in the English phonetic journals.

† There should be a rule to the effect that, *When a character is perverted from its original power, its form should show the variation.* Hence, if prejudice, or ignorance of Latin speech, should prevent a missionary from using (V) with its Latin consonant power, it should be marked to indicate its corrupt English power. Perhaps (ⱱ) might answer, or a break towards the left, in the left branch, like that of italic *k*. This would remove the confusion between *r* and *v* in writing.

To accommodate Sanscrit writing, Professor Lepsius uses (ṗ) for *p* and *h* in *uphold*, although all that was necessary was a statement of the fact that, in the Sanscrit alphabet, the sequents ph, bh, &c. (as well as a consonant and vowel in some cases) are supplied by a single character; a statement of this kind being considered sufficient in regard to *ps* having a single character in the Greek form of *ellipsis*. But whilst the spiritus asper and lenis marks are used in these heterogeneous and unauthorized modes, the former is used as a separate character for Arabic and Hebrew *'alef*. This is at least a doubtful view of the Greek spiritus lenis. As applied to a consonant, we see it in ἄῤῥην, *male* (and ἄρσην, because the surd aspirates *rh* and *s** are allied), and Dr. Lepsius admits an (ṙ) with a Greek key-word, and he would probably write the Welsh *rh* thus. As applied to a vowel, Chavée (Lexiologie Indo-européenne, p. 18), with great probability, explains the Greek spiritus lenis as the *slight breath* which precedes an initial vowel; for as the vibration of the vocal ligaments is due to the passing air, a little must necessarily pass before their quiescent state can be changed.

Professor Lepsius uses the acute accentual (ˊ)† over (*k*) for *tsh;* over (χ) to distinguish the German *ch* in *ich* from that in *ach;* after (*l*), &c. to denote the mouillé effect; and in (*ʻl*) the Welsh surd aspirate *l*, for some unexplained reason. To English *sh* and *zh* are assigned *s* and *z* surmounted by the (ˉ) mark for short quantity, — a perversion of a well-known mark, required, with the mark of length (as in Dacota *s* and *sh*, Riggs, pp. 184, 188), to distinguish long and short continuous

* But Dr. Latham, English Language, 1841, considers *s* the lenis of *sh*. He omits *h*, *wh*, *ng*, *rh*, from his System of Consonants, p. 112, and he considers the mutes specifically distinct to be no more than sixteen. To these add his "Semivowels, *w*, *y*," and "Liquids, *m*, *n*, *l*, *r*," *n* being given as the liquid of *t*, *d;* and *l*, of *k*, *g*.

† As an accent mark, this should be thick above, and for the secondary accent thicker below. If used for other purposes, it should be of equal thickness. Used with (ˈˈ) for sonant and surd, the middle part should be cut away to give the appearance of two dots in sloped directions.

consonants in some languages. S is thus prolonged in hissing. "The people of Mallicollo use R in many words, two or three being frequently joined together. ..... They express their admiration by hissing like a goose." (Cook's Second Voyage.)

A dot is used over (*n*) by Lepsius, for English and German *ng*, which is equivalent to representing *n* with a dotted *m*-character. Consistency should have required this dot to be (˘), because both indicate that the marked letter belongs to a posterior contact. Ellis's character is much better, — an *n*-character with the second limb ending like (*j*). As a capital (and capitals are of doubtful utility) that of Riggs is a good one, being (N) with the diagonal shaped like a sloped (J.) As a dot is the slightest of marks, it should be used (below the letters) to indicate those slight evanescent consonants and vowels which occur in some languages.

Rule IV., although it cannot be called unphilosophical, would deprive us of a well-known and exceedingly definite mode of notation with the aid of (' '), and obviate the necessity for many new characters in the course of linguistic discovery. By first assuming that *l* and *r* are "fricatives," Professor Lepsius admits (') with *l*, *r*, but denies it to *n*, *m*, as "explosives," *without providing a means to indicate the same phenomenon* in the latter case. Sjögren (Ossetische Sprachlehre, St. Petersburg, 1844) has a good notation for the aspirates. He uses the Russian alphabet for a basis, and instead of the ordinary *h*, he curves the end towards the left below the line, in the shape of (ɔ), then uses this appendage as the indicator of aspiration and spiration, by adding it to the stem of the Russian characters for *p*, *t*, *g*, and *k*, curving the last line of *k* backwards. For English *dz* he uses $\Delta_{\text{ɔ}}$, which is unnecessary, as the *z* character should appear fully, if the sound exists. Lepsius (p. 69) seems inclined to approve of this mode of writing $t_{\text{ɔ}}$, &c. Such forms should be left for the concurrent emission of consonants formed simultaneously (Rapp, I. 84). Thus a child learning to speak formed *l* by applying the tongue to the upper lip, and passing the voice over the lower lip, producing a sound having the quality of *l* and *'b*.

PROCEEDINGS

OF THE

ALBANY MEETING, 1856.

COMMUNICATIONS.

A. MATHEMATICS AND PHYSICS.

I. MATHEMATICS.

1. On the Laws of Human Mortality. By C. F. M'Cay, President of the South Carolina College, and Professor of Mathematics and Astronomy.

Various attempts have been made to determine the law of human mortality at different periods of life. In the early part of the eighteenth century, it was suggested that an equal number die at every age in a stationary population. The Northampton table of Dr. Price rather favored this suggestion, but other tables of mortality published by him in later editions of his book destroyed all confidence in this law. An arithmetical progression for early manhood, and a geometrical for old age, were then proposed. These not being satisfactory, Mr. Gompertz, in the Philosophical Transactions of 1825, brought forward a transcendental formula which represented the mortality from twenty to sixty years of age with great accuracy. In 1832, Mr. Edmonds extended this law to the whole period of human life, by using two formulas, one for manhood and the other for old age. As the dividing line between these two periods varied from fifty-five to sixty in different tables, and corresponded to no physiological change in our organization, the two laws of Mr. Edmonds did not receive much

favor; and as they involved six variable constants for every table, they were of little practical utility, either for the construction of tables, detecting anomalies, or harmonizing the irregularities which are found in all the statistics of human mortality.

I have obtained a single law which extends from early manhood to the extreme limit of human life. It was first discovered by an analysis of the Northampton and Carlisle tables; but it has been compared with a large number of others; and so complete is its agreement with all, that at no age does the calculated number of the living differ from the number given in the tables by a single year's mortality. The comparison has been made with all the tables to which I have had access. These comprise Halley's, the Switzerland, Vienna, Berlin, Brandenburg, Norwich, London, Northampton, Warrington, Chester, Stockholm, Shrewsbury, Kersebooms, Desparcieux, the three Swedish, the three Equitable, the Amicable, Montpelier, Duvillard's for France, Desparcieux's for monks and nuns, Farr's English, Farr's Northampton, Finlaison's, the Combined Experience of the London Insurance Companies, Nieson's Friendly Societies of Great Britain, Brussels, Hamburg, Amsterdam, Baltimore, Charleston, and others; and, except in the last six or eight years of life, in which no confidence is placed in any of the tables, the disagreement does not exceed the limits above mentioned. The number of the living, as calculated for the age of seventy-five, for example, is always greater than the actual number for seventy-six, and less than for seventy-four. When it is remembered that these tables have been constructed for different times and different countries, by various methods of interpolation, many of them on incomplete and unsatisfactory data, and some on wrong principles, such an agreement will be considered a decisive proof of the law which is proposed.

The extensive interests dependent on the law and the rate of mortality in the United States, Great Britain, and other countries, invest this matter with a high degree of practical importance, independent of the scientific interest attached to the application of a mathematical law to so uncertain a subject as the duration of human life.

If the Northampton table be examined, it will be found that the deaths are either stationary, or increase from the age of ten to sixty-one, and then diminish to the end of life. This increase and decrease are irregular, and follow no definite law. If the ratios of the dying

and the living at each age be examined, a continual increase will be observed. Excluding a few exceptional cases, this advance is found invariable in all the tables. It becomes more rapid at the older ages, but that its progress is not a geometrical progression will be evident by taking the logarithms of these ratios and observing their differences. If, however, these differences be examined, a geometrical progression will be discovered in them. This result shows that the rate of mortality or the ratio of the dying and the living is represented by the formula ab^{c^x}, in which x is the age, and a, b, and c are constants that differ for the several tables. For if the logarithm of this function be taken, it will be evident that a will disappear when the differences are found, and that a geometrical progression will be developed in which c is the constant multiplier.

Here are the numbers from the Northampton table for seven ages, at intervals of ten years: —

At the age of	25	35	45	55	65	75	85
The living were	4760	4010	3248	2448	1632	832	186
And the dying	75	75	78	82	80	80	41
The ratios are	.0158	.0187	.0240	.0336	.0492	.0943	.219
Their logarithms	—2.199	—2.272	—2.380	—2.526	—2.692	—2.974	—1.340
The differences are		.073	.108	.146	.166	.282	.366
The ratios are			1.48	1.35	1.14	1.70	1.30
Differences for twenty years			.181	.254	.312	.448	.648
The ratios are				1.40	1.23	1.44	1.45
Differences for thirty years				.327	.420	.594	.814
The ratios are					1.29	1.41	1.37
Differences for forty years					.493	.702	.960
The ratios are						1.42	1.37
Average ratios				1.39	1.38	1.36	1.39

None of these ratios differ much from each other, and the averages are very nearly the same. A slight increase of the deaths at sixty-five, and decrease at seventy-five, would make all agree very closely. As the mortality of any single year of life is not to be depended on, this agreement is sufficient to suggest the law which I have proposed. A more careful and extended comparison will be necessary to establish it.

Before doing this, however, let me refer to the principle which underlies it. Mr. Edmonds deduced his law from the supposition that our vital energy, or our power to resist the attacks of disease, decreases continually with advancing years, in such a manner that the portions

of our remaining mortality which we lose at each instant of time increase in geometrical progression. This hypothesis is exceedingly probable, but Mr. Edmonds erred in making these increments correspond to the deaths in a stationary population. By making them represent the increase in the rate of mortality, that is, in the ratio of the dying and the living, the law which I have proposed may be deduced.

If L represent the living and D the dying at any age x, a, b, and c being constants, then, according to Mr. Edmonds, the momentary decrement of L varies with L a^x or $-d\,\mathrm{L} = \mathrm{L}\ a\,b^x\,dx$. But if the increment is made to refer to the rate of mortality or the ratio of D to L, then if this be called r we have, $dr = r\,\beta\,c^x\,dx$.

Dividing this by r and integrating, we have

$$\log r = c^x \log b + \log a,$$

or

$$\log \frac{r}{a} = c^x \log b,$$

or

$$\frac{r}{a} = b^{c^x} \text{ or } r = a\,b^{c^x}.$$

The partial laws of Mr. Gompertz and Mr. Edmonds differ from mine fundamentally. In theirs, the number of the living follows a certain law; in mine, the law relates to the ratio of the dying and the living. Theirs was limited to manhood or to old age, mine includes both these periods. Mine involves only three constants, and by obtaining the average of these for all ages, the anomalies and errors of the tables may be checked and corrected.

To compare the proposed function with the tables, and to test it for all periods from manhood to old age, the Northampton table is given below, and along with it one calculated from the formula $r = a\,b^{c^x}$. In this $c = 1.031$, logarithm of $a = -2.986$, and logarithm of logarithm of $b = -2.995$. The agreement between the two tables is seen at a glance to be very close.

If the number of the living at the several ages be examined, it will be seen that the greatest difference occurs at the age of fifty-eight, and only amounts to thirteen, which is less than one sixth of a year's mortality at that age. That is, the number calculated to be alive at the age of fifty-eight is the number found to be living at the age of fifty-seven years and ten months. At eighty-five and eighty-six the difference is twelve, which is about a third of one year's mortality. All expire in both tables at the age of ninety-six; and even when the

number of the living is reduced to fifteen or twenty out of the ten thousand who are supposed to begin the table, the calculated number never disagrees with the tabular by a single year's mortality.

If the deaths in the two tables be examined, it will be found that for thirty ages the number is exactly the same in both. For nineteen they differ only one, and for only a single age, that of eighty-three, does the difference amount to five.

For the first ten years the whole number of the dying is 750, instead of 747. For the next ten it is 753, instead of 750. For each following decade the calculated numbers are

773 805 827 753 424 and 47,

while Dr. Price's are

778 819 806 763 423 and 46;

the difference never amounting to three per cent, and in five out of the eight ten-year periods being less than one per cent. The sum of all the positive and negative errors in the eight decades is only 58.

The most trying test is the annual ratio of mortality. From twenty-one to sixty these do not differ in the two tables by one fortieth of their amount; and up to the age of eighty they do not differ one twentieth; and at no time, to the very end of life, does the difference reach one fifth. These larger errors at the higher ages arise from Dr. Price's imperfect method of interpolation, since the whole number of the dying in the last two decades of life are almost exactly the same in both tables, being 424 and 47, instead of 423 and 46.

The agreement in all these four particulars is very satisfactory. With few of the other tables is it so close as in the Northampton. But in all, the differences are extremely small. At no period of life are the errors in different tables in one direction all positive or all negative. To bring out this comparison, the Equitable table of Mr. Morgan is subjoined. This is founded on the experience of the Equitable Insurance Company of London, from 1752 to 1829. In the calculated table, $c = 1.027$, logarithm of $a = -3.452$, and logarithm of log. $b = -1.311$.

Up to the age of eighty-five, the greatest difference between the calculated and the actual tables does not exceed six tenths of one year's mortality. The errors are, however, generally different from those of the Northampton.

Thus the greatest excess in the living at Northampton is at the age

of fifty-eight, while the greatest deficiency in the Equitable is at fifty-seven. The greatest deficiency in the Northampton is at seventy-two, and the greatest excess in the Equitable is at seventy-three.

Between thirty and forty, the deaths in both the Northampton and the Equitable are slightly too large; but in the seven other decades the positive errors of one table correspond to the negative errors in the other.

The smallness of all these errors, and their opposite directions in the several tables, furnish satisfactory proof that the formula we have given represents a true law of nature.

Among the inferences that may be drawn from the law are the following: —

1. The rate of mortality invariably increases from youth to old age.

2. This rate is continually accelerated, even in a higher ratio than in a geometrical progression.

3. In early manhood the rate does not differ much from a slow arithmetical progression.

4. There are no crises or climacterics at which the chances for life are stationary or improving.

5. There are no periods of slow and rapid increase succeeding each other; but one steady, invariable progress.

6. The law, though not the rate of mortality, is the same for city and country, for healthy and unhealthy places, for every age and country and locality; and this law is, that the differences of the logarithms of the rates of mortality are in geometrical progression.

Comparison of the Formula with the Northampton Table of Mortality.

Age.	Living of Dr. Price.	Dying.	Calculated Living.	Ratio of Dying and Living.	Number of Dying.	Errors of the Living.	Errors of the Dying.
20	5132	72	5132	.0147	75	0	3+
21	5060	75	5057	.0149	75	3—	0
22	4985	75	4982	.0151	75	3—	0
23	4910	75	4907	.0153	75	3—	0
24	4835	75	4832	.0156	75	3—	0
25	4760	75	4757	.0158	75	3—	0
26	4685	75	4682	.0160	75	3—	0
27	4610	75	4607	.0163	75	3—	0
28	4535	75	4532	.0165	75	3—	0
29	4460	75	4457	.0168	75	3—	0
30	4385	75	4382	.0171	75	3—	0
31	4310	75	4307	.0174	75	3—	0
32	4235	75	4232	.0177	75	3—	0
33	4160	75	4157	.0181	75	3—	0
34	4085	75	4082	.0184	75	3—	0
35	4010	75	4007	.0188	75	3—	0
36	3935	75	3932	.0192	75	3—	0
37	3860	75	3857	.0196	76	4—	1+

Age.	Living of Dr Price.	Dying.	Calculated Living.	Ratio of Dying and Living.	Number of Dying	Errors of the Living	Errors of the Dying.
38	3785	75	3781	.0201	76	5—	1+
39	3710	75	3705	.0205	76	6—	1+
40	3635	76	3629	.0209	76	6—	0
41	3559	77	3553	.0214	76	6—	1—
42	3482	78	3477	.0220	77	5—	1—
43	3404	78	3400	.0226	77	4—	1—
44	3326	78	3323	.0232	77	3—	1—
45	3248	78	3246	.0238	77	2—	1—
46	3170	78	3169	.0245	78	1—	0
47	3092	78	3091	.0252	78	1—	0
48	3014	78	3013	.0260	78	1—	0
49	2936	79	2935	.0268	79	1—	0
50	2857	81	2856	.0276	79	1—	2—
51	2776	82	2777	.0285	79	1+	3—
52	2694	82	2698	.0295	80	4+	2—
53	2612	82	2618	.0305	80	6+	2—
54	2530	82	2538	.0316	80	8+	2—
55	2448	82	2458	.0328	81	10+	1—
56	2366	82	2377	.0340	81	11+	1—
57	2284	82	2296	.0353	81	12+	1—
58	2202	82	2215	.0368	82	13+	0
59	2120	82	2133	.0384	82	13+	0
60	2038	82	2051	.0401	82	13+	0
61	1956	82	1969	.0419	83	13+	1+
62	1874	81	1886	.0439	83	12+	2+
63	1793	81	1803	.0460	83	10+	2+
64	1712	80	1720	.0483	83	8+	3+
65	1632	80	1637	.0505	83	5+	3+
66	1552	80	1554	.0533	83	2+	3+
67	1472	80	1471	.0562	83	1—	3+
68	1392	80	1388	.0594	82	4—	2+
69	1312	80	1306	.0629	82	6—	2+
70	1232	80	1224	.0667	81	8—	1+
71	1152	80	1143	.0708	81	9—	1+
72	1072	80	1062	.0753	80	10—	0
73	992	80	982	.0804	79	10—	1—
74	912	80	903	.0857	77	9—	3—
75	832	80	826	.0916	76	6—	4—
76	752	77	750	.0982	74	2—	3—
77	675	73	676	.105	71	1+	2—
78	602	68	605	.113	68	3+	0
79	534	65	537	.123	66	3+	1+
80	469	63	471	.133	63	2+	0
81	406	60	408	.144	59	2+	1—
82	346	57	349	.157	55	3+	2—
83	289	55	294	.171	50	5+	5—
84	234	48	244	.187	46	10+	2—
85	186	41	198	.205	41	12+	0
86	145	34	157	.225	35	12+	1+
87	111	28	122	.248	30	11+	2+
88	83	21	92	.274	25	9+	4+
89	62	16	67	.304	20	5+	4+
90	46	12	47	.338	16	1+	4+
91	34	10	31	.378	12	3—	2+
92	24	8	19	.423	8	5—	0
93	16	7	11	.475	5	5—	2—
94	9	5	6	.536	3	3—	2—
95	4	3	3	.607	2	1—	1—
96	1	1	1	.691	1	0	0

Comparison with Morgan's Equitable Table of Mortality.

Age.	Living in Table.	Dying.	Calculated Number of the Living.	Ratio by Formula.	Dying as Calculated	Errors in the Living	Errors in the Deaths.
20	4641	34	4641	.0063	29	0	4—
21	4607	33	4612	.0064	30	5+	3—
22	4574	33	4582	.0066	30	8+	3—
23	4541	33	4552	.0067	31	11+	2—
24	4508	33	4521	.0069	31	13+	2—
25	4475	34	4490	.0071	32	15+	2—
26	4441	34	4458	.0073	33	17+	1—
27	4407	34	4425	.0074	33	18+	1—
28	4373	34	4392	.0076	33	19+	1—
29	4339	34	4359	.0078	34	20+	0
30	4305	35	4325	.0081	35	20+	0
31	4270	35	4290	.0083	36	20+	1+
32	4235	36	4254	.0086	37	19+	1+
33	4199	37	4217	.0088	37	18+	0
34	4162	38	4180	.0091	38	18+	0
35	4124	38	4142	.0094	39	18+	1+
36	4086	39	4103	.0097	40	17+	1+
37	4047	40	4063	.0100	41	16+	1+
38	4007	42	4022	.0103	41	15+	1—
39	3965	43	3981	.0107	43	16+	0
40	3922	43	3938	.0111	44	16+	1+
41	3879	44	3894	.0115	45	15+	1+
42	3835	44	3849	.0119	46	14+	2+
43	3791	44	3803	.0124	47	12+	3+
44	3747	45	3756	.0129	48	9+	3+
45	3702	47	3708	.0134	50	6+	3+
46	3655	47	3658	.0140	51	3+	4+
47	3608	48	3607	.0147	53	1—	5+
48	3560	49	3554	.0153	54	6—	5+
49	3511	50	3500	.0160	56	11—	6+
50	3461	52	3444	.0168	58	17—	6+
51	3409	55	3386	.0177	60	23—	5+
52	3354	58	3326	.0185	62	28—	4+
53	3296	62	3264	.0195	64	32—	2+
54	3234	64	3200	.0206	66	34—	2+
55	3170	66	3134	.0217	68	36—	2+
56	3104	70	3066	.0229	70	38—	0
57	3034	75	2996	.0242	72	38—	3—
58	2959	79	2924	.0256	75	35—	4—
59	2880	84	2849	.0272	78	31—	6—
60	2796	88	2771	.0290	80	25—	8—
61	2708	90	2691	.0308	83	17—	7—
62	2618	91	2608	.0329	86	10—	5—
63	2527	93	2522	.0352	89	5—	4—
64	2434	95	2433	.0376	92	1—	3—
65	2339	100	2341	.0403	94	2+	6—
66	2239	105	2247	.0433	97	8+	8—
67	2134	108	2150	.0466	100	16+	8—
68	2026	111	2050	.0502	103	24+	8—
69	1915	115	1947	.0543	106	32+	9—
70	1800	115	1841	.0588	108	41+	7—
71	1685	115	1733	.0640	111	48+	4—
72	1570	115	1622	.0697	113	52+	2—
73	1455	115	1509	.0759	115	54+	0
74	1340	115	1394	.0829	116	54+	1+
75	1225	114	1278	.0906	116	53+	2+
76	1111	109	1162	.0995	118	51+	7+

Age.	Living in Table.	Dying.	Calculated Number of the Living.	Ratio by Formula.	Dying as Calculated.	Errors in the Living.	Errors in the Deaths.
77	1002	105	1046	.110	115	44+	10+
78	897	101	931	.121	113	34+	12+
79	796	96	818	.134	110	22+	14+
80	700	93	708	.149	105	8+	12+
81	607	90	603	.165	99	4—	9+
82	517	85	504	.184	93	13—	8+
83	432	83	411	.206	86	21—	3+
84	349	73	325	.230	75	24—	2+
85	276	61	250	.258	64	26—	3+
86	215	50	186	.292	54	29—	4+
87	165	42	132	.331	44	33—	2+
88	123	34	88	.378	33	35—	1—
89	89	22	55	.433	24	34—	2+
90	67	18	31	.498	15	36—	3—
91	49	14	16	.575	9	33—	5—
92	35	11	7	.670	5	28—	6—
93	24	8	2	.787	2	22—	6—
94	16	7	1	.933	1	16—	7—
95	9	5				9—	5—
96	4	3				4—	3—
97	1	1				1—	1—

2. Investigation and Calculation of the Results of a Process of Causation. By John Paterson.

"Felix qui potuit rerum cognoscere causas."—Virgil.

(1.) Causes are known to us only by their effects, and are introduced into mathematical reasoning by means of the measures of such effects in space and time. It is conducive to simplicity of calculation to take the effect produced in a given unit of time for unit of effect. The effect is the measure of its cause; and this cause, in its turn, may be the effect of a still higher cause, and so on for several steps in ascending order.

(2.) The phenomenon of a falling body affords an example of *subordinated causation*. The force of gravitation is a constant activity, generating velocity uniformly when acting upon a free material body; and this velocity moves the body with an accelerating rate of motion while it is itself being generated, and with a constant motion after its genesis has ceased. The force of gravity is here a primitive power, or first cause, having velocity for its immediate; while the velocity, in its turn, is the cause of the motion of the body, of its description of

a certain distance in space. The three terms of this ordinated series, in the descending order, may be denominated forces, or powers, or cause respectively of the *second*, *first*, and *zeroth* order, and denoted by the characters ϕ'', ϕ', and ϕ^0. To obtain suitable measures of the terms, the notion of time must be introduced by its unit 1_t, and combined with that of the unit of linear space 1_l. The moved body may be selected as unit of mass 1_μ; and the distance it describes in an arbitrarily chosen first unit of time $1'_t$ may be the unit of distance, or linear unit 1_l.

During the first unit of time $1'_t$, the velocity generated by gravity increases uniformly from zero to a certain ultimate value; and thenceforward, if isolated from the force of gravity, remains constant at that value; which is the same as saying that the unit of mass 1_μ moved from rest with a uniformly accelerated rate of motion during the first unit of time $1'_t$, through the unit of distance 1_l, and will thenceforward move uniformly with its last acquired rate of motion if the gravity were destroyed. With this last rate of motion, the mobile 1_μ will evidently describe a greater distance in the unit of time than it described while under acceleration in the time $1'_t$; and because the acceleration of the velocity varied regularly, and the units of space and time are of arbitrary magnitude, it follows that, when comparison is made of the effects produced by the velocity in two equal periods of time, the former with regularly varying acceleration, the latter with the ultimate constant value acquired in the first period, the distance described by the mobile 1_μ in the latter period will always be some definite number m of times the distance it described in the former. This is the same thing as saying that the ratio of the distance generated by the ultimate velocity generated in a given time, to the distance generated by the velocity during its own genesis, is that of $m : 1$.

From this it appears that the velocity generated in a given time has two different but fixedly related measures: first, the distance generated by the velocity during its own genesis, which may be termed its *simultaneous* measure; and, secondly, the distance that will be generated by the ultimate velocity remaining constant during an equal time after that of its genesis, and which may be termed its *successive* measure. When the time and distance generated during it are each unity, the former measure of the velocity is unity, and the latter measure will be m; and in this case, also, unity will be the simultaneous measure of

the force or power that generates in the unit of time the velocity whose simultaneous and successive measures are 1 and m, while m is the successive measure of the same force.

To calculate the value of m, let 1_λ be the unit of velocity, or that constant velocity which will carry the unit mass 1_μ the unit of distance 1_l in the unit of time 1_t. The mobile 1_μ has described the distance 1_l in the time $1'_t$ while the velocity $m\ 1_\lambda$ was generated; and it is thence evident that the mth part of the ultimate velocity $m\ 1_\lambda$ would carry 1_μ, in the unit of time, by a uniform rate of motion, through the same distance 1_l that it has been carried by a rate of motion accelerated from zero to the ultimate value m; and as the velocity increased uniformly during the unit of time $1'_t$, at the expiration of the first semi-unit of time $\frac{1}{2}' . 1'_t$ its ultimate value is $\frac{m}{2} . 1_\lambda$; with which value, remaining constant, the mobile will describe the distance $\frac{m}{2} . 1_l$ in a unit of time, and consequently the distance $\frac{m}{4} . 1_l$ in the second semi-unit of time $\frac{1}{2}'' . 1'_t$. The ultimate velocity $\frac{m}{2} . 1_\lambda$ generated in the first semi-unit of time $\frac{1}{2}' . 1'_t$, when referred to the measure of the effect it will produce in a time equal to that occupied in its own genesis, therefore becomes $\frac{m}{4} . 1_\lambda$; and the mth part of this ultimate velocity, taken constant, will describe with uniform motion the same distance in the time $\frac{1}{2}' . 1'_t$, that was really described by the accelerated motion produced by the uniformly increasing velocity from 0 to $\frac{m}{4} . 1_\lambda$: that common distance is therefore $\frac{1}{4} . 1_l$. During the second semi-unit of time $\frac{1}{2}'' . 1'_t$, another increment $\frac{m}{4} . 1_\lambda$ is generated by the gravitating force, which yields another increment $\frac{1}{4} . 1_l$ of distance during its genesis; and altogether there is generated the distance $(\frac{1}{4} + \frac{m}{4} + \frac{1}{4})\ 1_l = 1_l$ in the unit of time $1'_t$, and this equation gives $m = 2$. Therefore $2 . 1_\lambda = 2\,\phi'$ is the successive unit measure of the effect of the constant force ϕ'' of the second order, when the simultaneous measure of the same force is $1 . 1_\lambda = 1\,\phi'$, the last for the reason that $1 . 1_\lambda = 1\,\phi'$ produces the effect $1_l = 1\,\phi^0$ in the time $1'_t$.

(3.) Remark. It is undeniable that, in equal times, the ultimate

velocity will generate m times as much distance as will the uniformly increasing velocity; and as the units of time and of space are both arbitrary at the outset, and independent of each other, the magnitude of one of them may be changed without altering that of the other: then if the relation $m : 1$ of the successive to the simultaneous effects be true for any particular time t, it must necessarily be true for any other time $2\,t, 3\,t, \ldots n\,t$, because the unit of time may be changed without altering that of space.

(4.) If an activity increase from zero during a time t, by any regular law of variation, and thenceforward remain a constant activity with its ultimate value, its effect during an equal time must necessarily be some number m of times its effect while in its increasing state. From this it follows that the effect of the increasing activity will be equal to the mth part of its effect in an equal time with its ultimate constant value; and that the mth part of the ultimate value, taken constant during the time t, will produce in that time the same effect as that due to the increasing value.

(5.) The relation above investigated for a series of three ordinated terms ϕ'', ϕ', ϕ^0, may be generalized for any number n of terms; but to insure merely a sufficient and convenient number of terms for a demonstration, it suffices to take $n = 5$. The condition of unity of effect in the first unit of time will then give the simultaneous series of powers $1\,\phi^{v}$, $1\,\phi^{iv}$, $1\,\phi'''$, $1\,\phi''$, $1\,\phi'$, $1\,\phi^0$; while the corresponding successive series will be $1\,\phi^{v}$, $m\,\phi^{iv}$, $m'\,\phi'''$, $m''\,\phi''$, $m'''\,\phi'$, $1\,\phi^0$, where the coefficients m, m', m'', m''' are to be determined.

(6.) Let ϕ^{v} be a primitive cause, a constant activity, force, or power of the fifth order: it will produce a uniform effect in time, consisting in the generation of a certain amount of power of the fourth order ϕ^{iv} in each unit of time 1_t; which power ϕ^{iv} will generate power of the third order ϕ''', which generates power of the second order ϕ'', which generates power of the first order ϕ', which generates power of the order zero ϕ^0, with which the process terminates. Regarding first only the effects produced in the first unit of time $1'_t$, the final effect ϕ^0 will be some phenomenon regularly developed in time and space, and which may have for its unit measure the unit of distance 1_l described by the unit of mass 1_μ in the unit of time $1'_t$, under the action of the power of the first order ϕ'. This convention will give the coefficient to the final effect, and also to its immediate cause, of which

it is the unit measure; and further, as the power of the first order is the immediate effect of the power of the second order, and a like relation continues up to the primitive power of the fifth order, it follows that unity will be the coefficient of every term of the series of generating powers enumerated, so long as effects during the first unit of time $1'_t$ only are considered.

Thus the constant power $1\,\phi^{v}$ of the fifth order generates a unit of power of the fourth order $1\,\phi^{iv}$ in the first unit of time $1'_t$, when that power of the fourth order is measured by the power of the third order ϕ''' which it generates in the unit of time $1'_t$ of its own genesis. But this generated power of the fourth order increases from zero to some ultimate value during the time $1'_t$; with which ultimate value, remaining constant, it would generate some number m of times the amount of power of the third order in the succeeding unit of time $1''_t$, that was generated by it during the time of its increase or growth in $1'_t$. From this it follows that the mth part of the effect of the power ϕ^{iv} with its ultimate value, is equal to its effect in an equal time with its increasing value; and that the mth part of its ultimate value, taken constant, will produce the same effect in the same time as that produced by the increasing value.

(7.) Let the effects originated, produced, and terminated in the first unit of time $1'_t$ be termed *simultaneous;* and the effects whose causes are produced in the first unit of time, but which are themselves originated, produced, and terminated in the second unit of time $1''_t$, be termed *successive effects.* The simultaneous unit measure of the immediate effect of $1\,\phi^{v}$ is $1\,\phi^{iv}$; but its successive unit measure is $m\,\phi^{iv}$, since the ultimate value of ϕ^{iv} generates $m\,\phi'''$ in the time $1''_t$, while it generated only $1\,\phi'''$ while increasing in $1'_t$ to that ultimate value. As $1\,\phi^{v}$ is a uniform generator, its immediate effect increases uniformly from 0 to the value $m\,\phi^{iv}$ in the time $1'_t$, and therefore has the value $\frac{m}{2}\,\phi^{iv}$ at the expiration of the first semi-unit of time $\frac{1}{2}'\,.\,1'_t$. This power $\frac{m}{2}\,\phi^{iv}$, taken constant, would produce the effect $\frac{m}{2}\,\phi'''$ in a unit of time, and therefore actually does produce half that amount $\frac{m}{4}\,\phi'''$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$; and to find the effect of $\frac{m}{2}\,\phi^{iv}$ during the time $\frac{1}{2}'\,.\,1'_t$ of its own genesis or growth, it is only

necessary to divide the last-named amount by m, and thus get $\frac{1}{4}\,\phi'''$ for such effect. Another equal increment of power $\frac{m}{2}\,\phi^{\text{I}}$ is generated by $1\,\phi^{\text{V}}$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$, which generates in like manner the effect $\frac{1}{4}\,\phi'''$ in that time; and as the whole amount of power of the third order generated in the first unit of time must be unity, there appears the equation $(\frac{1}{4} + \frac{m}{4} + \frac{1}{4})\,\phi''' = 1\,\phi'''$, which gives $m = 2$ as the ratio of the successive to the simultaneous measure of the immediate effect of a cause (or of the cause itself) that increases uniformly in time. It is concluded, that, when a product increases uniformly in time, it is the immediate effect of a constant activity; and if the product be itself an activity, half its ultimate value is competent in effect to that of its uniformly increasing value for equal times. Hence the factor 2 and its reciprocal respectively serve to interchange the simultaneous and successive measures of the immediate causal effect of a primitive cause.

Thus accordingly as all is measured by the effects produced in the first unit of time $1'_t$, or as the immediate effect ϕ^{IV} of $1\,\phi^{\text{V}}$ in that time is measured by the effect itself produces in the second unit of time $1''_t$, there exists the first or second of the following notations of results:—

$$\tfrac{1}{2}'\,.\,1'_t + \tfrac{1}{2}''\,.\,1'_t = 1'_t. \qquad \tfrac{1}{2}'\,.\,1'_t + \tfrac{1}{2}''\,.\,1'_t = 1'_t.$$
$$\tfrac{1}{2}\,\phi_1{}^{\text{IV}} + \tfrac{1}{2}\,\phi_2{}^{\text{IV}} = 1\,\phi^{\text{IV}}; \text{ or } \tfrac{2}{2}\,\phi_1{}^{\text{IV}} + \tfrac{2}{2}\,\phi_2{}^{\text{IV}} = 2\,\phi^{\text{IV}}.$$

The constant $\frac{1}{2}\,\phi^{\text{IV}}$, and the uniformly increasing $\frac{2}{2}\,\phi^{\text{IV}} = 1\,\phi^{\text{IV}}$, are equivalent in their effects during the same semi-unit of time; and $1\,\phi_1{}^{\text{IV}}$ constant produces $\frac{2}{4}\,\phi'''$ in $\frac{1}{2}''\,.\,1'_t$, twice the effect $\frac{1}{4}\,\phi'''$ produced by $\frac{1}{2}\,\phi_2{}^{\text{IV}}$ constant, or by $1\,\phi_2{}^{\text{IV}}$ variable in that time.

Having now the simultaneous and successive semi-unit measures of the effect of $1\,\phi^{\text{V}}$ for the first unit of time $1'_t$, as also the simultaneous semi-unit measures of the effect of $1\,\phi^{\text{IV}}$ for the same time, the next step is to seek the corresponding successive semi-unit measures of the latter power ϕ^{IV}.

The simultaneous semi-unit measures of the immediate effect of the generated power of the fourth order $1\,\phi^{\text{IV}}$ are,

$$\left.\begin{aligned} \tfrac{1}{2}'\,.\,1'_t + \tfrac{1}{2}''\,.\,1'_t \\ \tfrac{1}{4}\,\phi_1{}''' + \tfrac{2}{4}\,\phi''' \\ + \tfrac{1}{4}\,\phi_2{}''' \end{aligned}\right\} = 1\,\phi'''.$$

These three increments of generated power of the third order are themselves generating powers, and are the constant equivalents in effect of so many increments of generating power of the same order, increasing from zero, during the same semi-units of time. Like as $\frac{1}{2}\phi^{IV}$ was the constant equivalent in effect to the increment increasing from zero to the ultimate value $\frac{m}{2}\phi^{IV}$ in the semi-unit of time, and m was found to be 2; so is $\frac{1}{4}\phi'''$ the constant equivalent in effect to an increment increasing from zero to some ultimate value $\frac{m'}{4}\phi'''$ in the semi-unit of time, and m' is now sought. Form the equation

$$\tfrac{1}{2}'.1'_t + \tfrac{1}{2}''.1'_t = 1'_t:$$

$$\left.\begin{aligned}\frac{m'}{4}\phi_1''' + \frac{2m'}{4}\phi''' \\ + \frac{m'}{4}\phi_2'''\end{aligned}\right\} = m'\phi''';$$

and observe that while $\frac{m'}{4}\phi_1'''$ will be a constant generator during the second semi-unit of time $\frac{1}{2}''.1'_t$, the increment $\frac{2m'}{4}\phi'''$, being generated by $\frac{1}{2}\phi_1^{IV}$ constant during $\frac{1}{2}''.1'_t$, increases uniformly during that time; and therefore its effect must be divided by 2, when it becomes equal to that of $\frac{m'}{4}\phi'''$ for the same time.

Now the generated power of the third order increases from zero to the ultimate value $\frac{m'}{4}\phi'''$ during the first semi-unit of time $\frac{1}{2}'.1'_t$; with which value it would generate the increment of power of the second order $\frac{m'}{4}\phi''$ in a unit of time, and therefore actually will generate the amount $\frac{m'}{8}\phi''$ in the second semi-unit of time $\frac{1}{2}''.1'_t$, and consequently $\frac{1}{8}\phi''$ the m'th part of this amount in the time of its own genesis in the first semi-unit $\frac{1}{2}'.1'_t$; and an equal amount will be due to the generating increment $\frac{m'}{4}\phi_2'''$ generated in the second semi-unit $\frac{1}{2}''.1'_t$ of time. The increment $\frac{2m'}{4}\phi'''$, being the immediate effect of the constant generator $\frac{1}{2}\phi_1^{IV}$ during the time $\frac{1}{2}''.1'_t$, increases uniformly, and therefore its effect in that time will be $\frac{2}{2}.\frac{m'}{4}\phi'' = \frac{m'}{4}\phi''$

in a unit of time, and consequently $\frac{m'}{8}\,\phi''$ in the semi-unit of time $\frac{1}{2}''.1'_t$. Altogether there arises the equation

$$(\tfrac{1}{8} + \frac{m'}{8} + \tfrac{2}{2}\cdot\frac{m'}{8} + \tfrac{1}{8})\,\phi'' = 1\,\phi'',$$

which gives $m' = 3$ as the ratio of the successive to the simultaneous measures of the mediate effects of a uniformly increasing cause, or of the *bimediate* effects of a constant cause. Hence, as the measure of the effect is the measure of the cause, the factor 3 and its reciprocal respectively serve to interchange the simultaneous and successive measures of the mediate causal effect of a primitive cause.

With $m' = 3$, the successive equations of the generated power of the third order becomes $(\frac{3}{4} + \frac{2}{4}\cdot\frac{3}{4} + \frac{3}{4})\,\phi''' = 3\,\phi'''$; and the simultaneous equation of the generated power of the second order at the same time is

$$\left.\begin{aligned} &\tfrac{1}{2}'.1'_t + \tfrac{1}{2}''.1'_t = 1'_t: \\ &\tfrac{1}{8}\,\phi_1'' + \tfrac{3}{8}\,\phi_1'' \\ &\qquad + \tfrac{3}{8}\,\phi_2'' \\ &\qquad + \tfrac{1}{8}\,\phi_2'' \end{aligned}\right\} = 1\,\phi''.$$

Each of these increments is the constant equivalent in effect for the same time, of so much variable power of the second order, increasing from zero to some ultimate value denoted by m'' times the numerical coefficient of the increment considered. During the first semi-unit of time $\frac{1}{2}'.1'_t$, there will be generated a quantity of power of the second order increasing from zero to the ultimate value $\frac{m''}{8}\,\phi''$; and similarly for each of the other increments in the equation, which will then be written for successive measure,

$$\left.\begin{aligned} &\tfrac{1}{2}'.1'_t + \tfrac{1}{2}''.1'_t = 1'_t: \\ &\frac{m''}{8}\,\phi_1'' + \frac{3\,m''}{8}\,\phi_1'' \\ &\qquad + \frac{3\,m'}{8}\,\phi_2'' \\ &\qquad + \frac{m''}{8}\,\phi_2'' \end{aligned}\right\} = m''\,\phi''.$$

Now $\frac{m''}{8}\,\phi_1''$ would produce the effect $\frac{m''}{8}\,\phi'$ in a unit of time, and therefore actually generates half that amount $\frac{m''}{16}\,\phi'$ in the semi-unit

$\frac{1}{2}''.1'_t$ of time, and consequently the m''th part $\frac{1}{16}\phi'$ of this amount in the time $\frac{1}{2}'.1'_t$; which last is also the amount generated by $\frac{m''}{8}\phi_2''$ in $\frac{1}{2}''.1'_t$. The increment $\frac{3\,m''}{8}\phi''$, being the immediate effect of the constant generator $\frac{3}{4}\phi_1'''$ during the time $\frac{1}{2}''.1'_t$, must have its effect divided by 2, which thus becomes $\frac{3}{2}.\frac{m''}{8}\phi'$ for the unit of time, and therefore $\frac{3}{2}.\frac{m''}{16}\phi'$ for the time $\frac{1}{2}''.1'_t$; and the increment $\frac{3\,m''}{8}\phi_2''$, which is the immediate effect of the uniformly increasing generator $\frac{6}{4}\phi'''$, or the mediate effect of the constant generator $\frac{1}{2}\phi_1^{\text{IV}}$, during the time $\frac{1}{2}''.1'_t$, must have its effect divided by 3, which thus becomes $\frac{3}{3}.\frac{m''}{8}\phi'$ for the unit of time, and therefore $\frac{3}{3}.\frac{m''}{16}\phi'$ for the time $\frac{1}{2}''.1'_t$. Altogether there arises the equation

$$(\tfrac{1}{16}+\frac{m''}{16}+\tfrac{3}{2}.\frac{m''}{16}+\tfrac{3}{3}.\frac{m''}{16}+\tfrac{1}{16})\,\phi' = 1\,\phi',$$

which gives $m'' = 4$ as the ratio of the successive to the simultaneous measure of the trimediate effects of a constant cause. Hence, the factor 4 and its reciprocal mutually serve to interchange the simultaneous and successive measures of the bimediate causal effects of a primitive cause.

With $m'' = 4$, the successive equation of the generated power of the second order becomes $(\frac{4}{8}+\frac{12}{8}+\frac{12}{8}+\frac{4}{8})\,\phi'' = 4\,\phi''$; and the simultaneous equation of the generated power of the first order at the same time is

$$\left.\begin{array}{l} \frac{1}{2}'.1'_t+\frac{1}{2}''.1'_t = 1'_t: \\ \frac{1}{16}\phi_1'+\frac{4}{16}\phi_1' \\ \qquad +\frac{8}{16}\phi' \\ \qquad +\frac{4}{16}\phi_2' \\ \qquad +\frac{1}{16}\phi_2' \end{array}\right\} = 1\,\phi'.$$

Each increment is the constant equivalent in effect, for the same time, of so much power of the first order, increasing from zero to some ultimate value denoted by m''' times its numerical coefficient. During the first semi-unit of time $\frac{1}{2}'.1'_t$, the generated power of the first order increases from zero to the ultimate value $\frac{m'''}{16}\phi'$; and simi-

larly for each of the other increments, so that the equation for successive measures is

$$\tfrac{1}{2}' \cdot 1'_t + \tfrac{1}{2}'' \cdot 1'_t = 1'_t :$$

$$\left.\begin{aligned} &\frac{m'''}{16}\,\phi_1' + \frac{4\,m'''}{16}\,\phi_1' \\ &\qquad + \frac{6\,m'''}{16}\,\phi' \\ &\qquad + \frac{4\,m'''}{16}\,\phi_2' \\ &\qquad + \frac{m'''}{16}\,\phi_2' \end{aligned}\right\} = m'''\,\phi'.$$

Now $\frac{m'''}{16}\,\phi_1'$ would produce the effect $\frac{m'''}{16}\,\phi^0$ in a unit of time, and therefore actually does generate half that amount $\frac{m'''}{32}\,\phi^0$ in the second semi-unit of time $\frac{1}{2}'' \cdot 1'_t$, and consequently the m'''th part of it $\frac{1}{32}\,\phi^0$ in the first semi-unit $\frac{1}{2}' \cdot 1'_t$ of time; which last is also the amount generated by $\frac{m'''}{16}\,\phi_2'$ in the second semi-unit $\frac{1}{2}'' \cdot 1'_t$ of time.

The increment $\frac{4\,m'''}{16}\,\phi_1'$ is the immediate effect of the constant generator $\frac{1}{8}\,\phi_1''$ during the time $\frac{1}{2}'' \cdot 1'_t$, and must therefore have its effect divided by 2, which thus becomes $\frac{1}{2} \cdot \frac{m'''}{16}\,\phi^0$ for the unit of time, and consequently $\frac{1}{2} \cdot \frac{m'''}{32}\,\phi^0$ for the time $\frac{1}{2}'' \cdot 1'_t$.

The increment $\frac{6\,m'''}{16}\,\phi'$ is the mediate effect of the constant generator $\frac{3}{4}\,\phi_1'''$ during the time $\frac{1}{2}'' \cdot 1'_t$, and must therefore have its effect divided by 3, which thus becomes $\frac{6}{3} \cdot \frac{m'''}{16}\,\phi^0$ for the unit of time, and consequently $\frac{6}{3} \cdot \frac{m'''}{32}\,\phi^0$ for the time $\frac{1}{2}'' \cdot 1'_t$.

The increment $\frac{4\,m'''}{16}\,\phi_2'$ is the bimediate effect of the constant generator $\frac{1}{2}\,\phi_1^{IV}$ during the time $\frac{1}{2}'' \cdot 1'_t$, and must have its effect divided by 4, which thus becomes $\frac{4}{4} \cdot \frac{m'''}{16}\,\phi^0$ for the unit of time, or $\frac{4}{4} \cdot \frac{m'''}{32}\,\phi^0$ for the time $\frac{1}{2}'' \cdot 1'_t$. All together fetch the equation

$$(\tfrac{1}{32} + \frac{m'''}{32} + \tfrac{4}{2} \cdot \frac{m'''}{32} + \tfrac{6}{3} \cdot \frac{m'''}{32} + \tfrac{4}{4} \cdot \frac{m'''}{32} + \tfrac{1}{32})\ \phi^0 = 1\ \phi^0,$$

which gives $m''' = 5$ as the ratio of the successive to the simultaneous measure of the quatrimediate effects of a constant cause. Hence, the factor 5 and its reciprocal mutually serve to interchange the simultaneous and successive measures of the trimediate causal effects of a primitive cause.

With $m''' = 5$, the successive equation of the generated power of the first order becomes $(\frac{5}{16} + \frac{20}{16} + \frac{30}{16} + \frac{20}{16} + \frac{5}{16})\ \phi' = 5\ \phi'$; and the simultaneous equation of the generated power of the order zero at the same time is $(\frac{1}{32} + \frac{5}{32} + \frac{10}{32} + \frac{10}{32} + \frac{5}{32} + \frac{1}{32})\ \phi^0 = 1\ \phi^0$.

(8.) In an investigation so opposed to the ordinary methods of mathematical reasoning, some repetitions may be allowed.

Two principles govern and suffice to explain the process of mathematical development: —

I. The measure of an effect stands as the measure of its cause.

II. The successive and simultaneous measures of a regularly increasing cause or power have to each other a determinate ratio.

Under the first principle, it is allowable to select for unit of effect that which is produced in the unit of time, which will then be the unit measure of its immediate cause: this cause, in its turn, may be the immediate effect of a cause one degree higher, of which it will, consequently, be also the unit measure; and so on, for any number of steps of ascent fixed upon. If, then, the primitive cause or power selected be of the fifth order, there will be established the series of simultaneous causes or powers $1\ \phi^{v}$, $1\ \phi^{iv}$, $1\ \phi'''$, $1\ \phi''$, $1\ \phi'$, $1\ \phi^0$; the measure of each, throughout the series, being unity *in and for* the first unit of time $1'$, of the operative process.

The second principle merely embodies the self-evident proposition, that if an activity increase from zero according to some regular law during a given time, and then remain constant with its ultimate value for an equal time, its effect in the latter interval will be some definite number of times its effect in the former interval of time. This proposition embraces two precepts of direct application to the construction and interpretation of the process of development.

1. If the ultimate value of an activity enable it to produce m times its preceding effect, the times being equal, then the mth part of the successive effect is equal to the simultaneous effect of the activity.

2. The mth part of the ultimate value is the constant value of the activity that will produce the same effect it did produce while increasing from zero to that ultimate value, the times being equal.

(9.) The power of the fifth order $1\,\phi^{v}$ is a constant uniform activity, and hence generates power of the fourth order uniformly in time. As its simultaneous measure, according to the first principle, is to be unity, its effect in and for the time $1'_t$ is $1\,\phi^{iv}$; and as its action is uniform, it generates $\frac{1}{2}\,\phi_1{}^{iv}$ and $\frac{1}{2}\,\phi_2{}^{iv}$ in the semi-units of time $\frac{1}{2}'.\,1'_t$ and $\frac{1}{2}''.\,1'_t$ respectively. These measures are constant values, and are the same as though ϕ^{iv} were an inactivity. But the generated power of the fourth order is itself an activity, and generates power of the third order both during and after its own genesis in the first unit of time $1'_t$; and as it increases regularly from zero during the time of its genesis, it is evident that with its ultimate constant magnitude during an equal time it will produce some definite number m of times its preceding effect. Consequently, the amount of power of the fourth order generated by $1\,\phi^{v}$ in the time $1'_t$, for the time $1''_t$, will be expressed by $m\,\phi^{iv}$, or m will be the ratio of the successive to the simultaneous measure of the generated power of the fourth order; and therefore, by uniformity of genesis, the amounts for the times $\frac{1}{2}'.\,1'_t$ and $\frac{1}{2}''.\,1'_t$ respectively are $\frac{1}{2}\,m\,\phi_1{}^{iv}$ and $\frac{1}{2}\,m\,\phi_2{}^{iv}$. The ultimate value or simultaneous measure $\frac{1}{2}\,m\,\phi_1{}^{iv}$ would generate $\frac{1}{2}\,m\,\phi'''$ in a unit of time, and therefore actually does generate $\frac{1}{4}\,m\,\phi'''$ in the semi-unit of time $\frac{1}{2}''.\,1'_t$; and consequently, by the first precept, it has generated $\frac{1}{4}\,\phi'''$ in the time $\frac{1}{2}'.\,1'_t$ of its own genesis. The increment $\frac{1}{2}\,m\,\phi_2{}^{iv}$ generated by $1\,\phi^{v}$ in the second semi-unit of time $\frac{1}{2}''.\,1'_t$, would also generate $\frac{1}{2}\,m\,\phi'''$ in a unit of time, or $\frac{1}{4}\,m\,\phi'''$ in a semi-unit of time after its genesis, and therefore actually has generated $\frac{1}{4}\,\phi_2'''$ in the time $\frac{1}{2}''.\,1'_t$ of its own genesis. There is thus obtained the equation $(\frac{1}{4}+\frac{m}{4}+\frac{1}{4})\,\phi'''=1\,\phi'''$, the simultaneous measure of the generated power of the third order for the time $1'_t$; which gives $m=2$: whence $2\,\phi^{iv}$ is the ultimate value, or the successive measure of the power of the fourth order generated by $1\,\phi^{v}$ in a unit of time, or $2:1$ is the ratio of the successive and simultaneous measures of a power that increases uniformly.

The increment generated by $1\,\phi^{v}$ in the times $\frac{1}{2}'.\,1'_t$ and $\frac{1}{2}''.\,1'_t$ are therefore respectively $\frac{2}{2}\,\phi_1{}^{iv}=1\,\phi_1{}^{iv}$ and $\frac{2}{2}\,\phi_2{}^{iv}=1\,\phi_2{}^{iv}$. Each of these increments increases from zero to $1\,\phi^{iv}$ in the semi-unit of time;

and by the second precept, the half of the ultimate value, or $\frac{1}{2}\phi^{IV}$, taken constant, will produce the same effect as the variable in the same time. Now $\frac{1}{2}\phi^{IV}$ would generate $\frac{1}{2}\phi'''$ in a unit of time, or $\frac{1}{4}\phi'''$ in a semi-unit of time. Therefore the constants $\frac{1}{2}\phi_1{}^{IV}$ and $\frac{1}{2}\phi_2{}^{IV}$ produce the same effects $\frac{1}{4}\phi_1{}'''$ and $\frac{1}{4}\phi_2{}'''$ as the variables $\frac{2}{2}\phi_1{}^{IV}$ and $\frac{2}{2}\phi_2{}^{IV}$ in the times $\frac{1}{2}'.1'_t$ and $\frac{1}{2}''.1'_t$ respectively, and the constant $\frac{2}{2}\phi_2{}^{IV}$ produces $\frac{2}{4}\phi'''$ in $\frac{1}{2}''.1'_t$; making in all $(\frac{1}{4}+\frac{2}{4}+\frac{1}{4})\phi''' = 1\phi'''$, which is the same as though ϕ''' were an inactivity. But the generated power of the third order is itself an activity, and generates power of the second order increasingly during its own genesis, and uniformly afterwards.

The constant $\frac{1}{2}\phi_1{}^{IV}$ (equivalent of the variable increasing from zero to $\frac{2}{2}\phi_1{}^{IV}$) would produce the effect $\frac{m'}{4}\phi_1{}'''$ in the time $\frac{1}{2}'.1'_t$: this increment $\frac{m'}{4}\phi_1{}'''$ would produce the effect $\frac{m'}{4}\phi''$ in a unit of time after its genesis, and therefore does produce the effect $\frac{m'}{8}\phi_1{}''$ in the time $\frac{1}{2}''.1'_t$, and consequently has produced the effect $\frac{1}{8}\phi_1{}''$ in the time $\frac{1}{2}'.1'_t$ of its own genesis; and the same amount $\frac{1}{8}\phi_2{}''$ will result from the constant increment $\frac{1}{2}\phi_2{}^{IV}$ (equivalent of the variable $\frac{2}{2}\phi_2{}^{IV}$) in the time $\frac{1}{2}''.1'_t$. But the increment $\frac{m'}{4}\phi_1{}'''$ (which generates $\frac{m'}{8}\phi_1{}''$ in $\frac{1}{2}''.1'_t$, and has generated $\frac{1}{8}\phi_1{}''$ in $\frac{1}{2}'.1'_t$) was really generated by the variable $\frac{2}{2}\phi_1{}^{IV}$ in $\frac{1}{2}'.1'_t$; and as this increment has increased uniformly during $\frac{1}{2}'.1'_t$, and remains constant during $\frac{1}{2}''.1'_t$, it will in this time generate twice its preceding effect, which is therefore $2\frac{m'}{4}\phi'''$. This increment $2\frac{m'}{4}\phi'''$, remaining constant after its genesis in $\frac{1}{2}''.1'_t$, would produce the effect $2\frac{m'}{4}\phi''$ in a unit of time, or $2\frac{m'}{8}\phi''$ in a semi-unit of time; but being itself generated by the constant $2\frac{m'}{4}\phi'''$ in the time $\frac{1}{2}''.1'_t$, it increased uniformly, and does therefore generate half the preceding effect in that time, that is, the amount $\frac{2}{2}.\frac{m'}{8}\phi''$. Thus is obtained the equation $(\frac{1}{8}+\frac{m'}{8}+\frac{2}{2}.\frac{m'}{8}+\frac{1}{8})\phi'' = 1\phi''$, which gives $m' = 3$; whence $3\phi'''$ is the ultimate value of the power of the third

order generated by the power of the fourth order increasing from zero to the value $2\,\phi^{iv}$ in the unit of time $1'_t$. The generated power of the third order $3\,\phi'''$ will produce thrice the effect in the time $1''_t$, that it produced during its genesis in the time $1'_t$: also its ultimate value for the time $\frac{1}{2}'.1'_t$ is $\frac{3}{4}\,\phi'''$, which generates $\frac{3}{8}\,\phi''$ in the time $\frac{1}{2}''.1'_t$; and one third of which value, $\frac{1}{4}\,\phi'''$, being constant during the time $\frac{1}{2}'.1'_t$, would generate $\frac{1}{8}\,\phi''$, the same actually generated by the variable $\frac{3}{4}\,\phi'''$ in that time.

To find the measures of the generated increments of power of the second order in terms of their effect in power of the first order, observe that the constant $\frac{1}{4}\,\phi_1'''$ (equivalent of the variable increasing from zero to $\frac{3}{4}\,\phi_1'''$) would generate the increment $\frac{m''}{8}\,\phi_1''$ in the time $\frac{1}{2}'.1'_t$; which increment $\frac{m''}{8}\,\phi_1''$ would generate the effect $\frac{m''}{8}\,\phi_1'$ in a unit of time, and therefore does generate $\frac{m''}{16}\,\phi_1'$ in the time $\frac{1}{2}''.1'_t$, and consequently has generated $\frac{1}{16}\,\phi_1'$ during the time of its own genesis in $\frac{1}{2}'.1'_t$; and the same amount $\frac{1}{16}\,\phi_2'$ will result from the constant increment $\frac{1}{4}\,\phi_2'''$ (equivalent of the variable $\frac{3}{4}\,\phi_2'''$) in the time $\frac{1}{2}''.1'_t$. But the increment $\frac{m''}{8}\,\phi_1''$ (which generates $\frac{m''}{16}\,\phi_1'$ in $\frac{1}{2}''.1'_t$, and has generated $\frac{1}{16}\,\phi_1'$ in $\frac{1}{2}'.1'_t$) was really generated by the variable $\frac{3}{4}\,\phi_1'''$ in $\frac{1}{2}'.1'_t$; and as this increment has increased in a triplicate ratio during $\frac{1}{2}'.1'_t$, and remains constant during $\frac{1}{2}''.1'_t$, it will in this time generate thrice its preceding effect, which is therefore $3\,\frac{m''}{8}\,\phi''$. This increment $3\,\frac{m''}{8}\,\phi''$, remaining constant after its genesis in $\frac{1}{2}''.1'_t$, would generate $3\,\frac{m''}{8}\,\phi'$ in a unit of time, or $3\,\frac{m''}{16}\,\phi'$ in a semi-unit of time; but being itself generated by the constant $\frac{3}{4}\,\phi_1'''$ in the time $\frac{1}{2}''.1'_t$, it increases uniformly, and does therefore generate half the preceding effect in that time, that is, the amount $\frac{3}{2}.\frac{m''}{16}\,\phi'$. The increment $2.\frac{3}{4}\,\phi'''$, being constant during $\frac{1}{2}''.1'_t$, must have its effect during that time divided by 2, when it will be $3\,\frac{m''}{8}\,\phi_2''$, the same as that of the increment $\frac{3}{4}\,\phi_1'''$: the effect of $\frac{3}{8}\,m''\,\phi_1''$ during a semi-unit of time after its genesis would be $\frac{3}{16}\,m''\,\phi'$; but since it has

increased during $\frac{1}{2}''.1'_t$ in a triplicate ratio, its effect in that time is $\frac{3}{8}.\frac{m''}{16}\phi_1'$. Thus is obtained the equation

$$(\tfrac{1}{16}+\frac{m''}{16}+\tfrac{3}{2}\frac{m''}{16}+\tfrac{3}{3}\frac{m''}{16}+\tfrac{1}{16})\,\phi'=1\,\phi',$$

which gives $m''=4$; whence $4\,\phi''$ is the ultimate value of the power of the second order generated by the power of the third order while increasing from zero to the value $3\,\phi'''$ in the first unit of time $1'_t$. The generated power of the second order $4\,\phi''$ will produce four times the effect in the time $1''_t$ that it produced in the time of its genesis in $1'_t$.

The constant $\frac{1}{8}\phi_1''$ (equivalent of the variable increasing from zero to the value $\frac{4}{8}\phi_1''$ in the time $\frac{1}{2}'.1'_t$) would generate the increment $\frac{m'''}{16}\phi_1'$ in that time; which last increment would generate the effect $\frac{m'''}{16}\phi_1^0$ in a unit of time, and therefore does generate $\frac{m'''}{32}\phi_1^0$ in the time $\frac{1}{2}''.1'_t$, and consequently has generated $\frac{1}{32}\phi_1^0$ in the time $\frac{1}{2}'.1'_t$ of its own genesis; and the same amount $\frac{1}{32}\phi_2^0$ will result from the constant increment $\frac{1}{8}\phi_2''$ (equivalent of the variable $\frac{4}{8}\phi_2''$ in the time $\frac{1}{2}''.1'_t$). But the increment $\frac{m'''}{16}\phi_1'$ was really generated by the variable $\frac{4}{8}\phi_1''$ in $\frac{1}{2}'.1'_t$; and as this increment has increased in a quadruplicate ratio, during $\frac{1}{2}'.1'_t$, and remains constant during $\frac{1}{2}''.1'_t$, it will in this time generate $4\,\frac{m'''}{16}\phi_1'$, four times its preceding effect. This increment $4\,\frac{m'''}{16}\phi_1'$, remaining constant after its genesis in $\frac{1}{2}''.1'_t$, would generate $4\,\frac{m'''}{16}\phi_1^0$ in a unit of time, or $\frac{4\,m'''}{32}\phi_1^0$ in a semi-unit of time; but being itself generated by the constant $\frac{4}{8}\phi_1''$ in the time $\frac{1}{2}''.1'_t$, it increases uniformly, and therefore generates $\frac{4}{2}.\frac{m'''}{32}\phi_1^0$ in that time.

The increment $\frac{3}{4}\phi_1'''$ is constant during $\frac{1}{2}''.1'_t$, and generates $3.\frac{4}{8}\phi_1''$ in that time; this increment, increasing uniformly, generates $\frac{3}{2}.\frac{4\,m'''}{16}\phi_1'$ in the time $\frac{1}{2}''.1'_t$; and this last increment, remaining constant after its genesis, would generate $\frac{6\,m'''}{16}\phi^0$ in a unit of time, or

$\frac{6\,m'''}{32}\,\phi^0$ in a semi-unit of time; but being itself generated in $\frac{1}{2}''\,.\,1'_t$ a uniformly increasing power, its effect increases in a triplicate ra and therefore it generates $\frac{6}{3}\,.\,\frac{m'''}{32}\,\phi^0$ in that time.

The increment $\frac{2}{2}\,\phi_1{}^{IV}$ is constant during $\frac{1}{2}''\,.\,1'_t$, and gener $2\,.\,\frac{3}{4}\,\phi'''$ in that time: this increment, increasing uniformly, gener $\frac{2}{2}\,.\,\frac{3}{8}\,\frac{4}{5}\,\phi''$ in the time $\frac{1}{2}''\,.\,1'_t$: this increment, increasing in a dupli ratio, generates $\frac{2}{3}\,.\,\frac{4\,m'''}{16}\,\phi'$ in the time $\frac{1}{2}''\,.\,1'_t$; and this last in ment, remaining constant after genesis, would generate $\frac{4\,m'''}{16}\,\phi^0$ unit of time, or $\frac{4\,m'''}{32}\,\phi^0$ in a semi-unit of time; but being itself erated in $\frac{1}{2}''\,.\,1'_t$ by a power that increases in a triplicate ratio, its e increases in a quadruplicate ratio, and therefore reduces to $\frac{4}{4}\,.\,\frac{m'''}{32}$ for the time $\frac{1}{2}''\,.\,1'_t$. There is thus obtained the equation

$$(\tfrac{1}{32} + \frac{m'''}{32} + \tfrac{4}{2}\,.\,\frac{m'''}{32} + \tfrac{6}{3}\,.\,\frac{m'''}{32} + \tfrac{4}{4}\,.\,\frac{m'''}{32} + \tfrac{1}{32})\,\phi^0 = 1\,\phi^0,$$

which gives $m''' = 5$; whence $5\,\phi'$ is the ultimate value of the po of the first order generated by the power of the second order incr ing from zero to $4\,\phi''$, generated by the power of the third order creasing from zero to $3\,\phi'''$, generated by the power of the fourth o increasing from zero to $2\,\phi^{IV}$, generated by the constant primitive p er of the fifth order $1\,\phi^V$ in the first unit of time $1'_t$.

(10.) A reference to the accompanying table may assist to re the steps of the investigation more intelligible. Under the first d ion of effects, the dotted lines refer to the effects that *would be* duced during the times for which they are drawn, while the black l indicate the effects that *are* produced. The last division exhibits corresponding measures of the effects in space, in and for the $\frac{1}{2}'\,.\,1'_t + \frac{1}{2}''\,.\,1'_t = 1'_t$.

(11.) In the following tablet of successive measures, the succ sively introduced numerical factors are all retained in the subseque coefficients: —

$1\,\phi^{v}$:

$\frac{1}{2}'.1'_t$	+	$\frac{1}{2}''.1'_t$	$= 1'_t.$
$2.\frac{1}{2}\,\phi^{iv}$	+	$2.\frac{1}{2}\,\phi^{iv}$	$= 2\,\phi^{iv};$
$\frac{2}{2}.3.\frac{1}{2^2}\,\phi'''$	+	$2.3.\frac{1}{2^2}\,\phi'''$	$= 3\,\phi'''$;
	+	$\frac{2}{2}.3.\frac{1}{2^2}\,\phi'''$	
$\frac{2}{2}.\frac{3}{3}.4.\frac{1}{2^3}\,\phi''$	+	$3.4.\frac{1}{2^3}\,\phi''$	
	+	$\frac{2}{2}.3.4.\frac{1}{2^3}\,\phi''$	$= 4\,\phi''$;
	+	$\frac{2}{2}.\frac{3}{3}.4.\frac{1}{2^3}\,\phi''$	
$\frac{2}{2}.\frac{3}{3}.\frac{4}{4}.5.\frac{1}{2^4}\,\phi'$	+	$4.5.\frac{1}{2^4}\,\phi'$	
	+	$\frac{3}{2}.4.5.\frac{1}{2^4}\,\phi'$	
	+	$\frac{2}{2}.\frac{3}{3}.4.5.\frac{1}{2^4}\,\phi'$	$= 5\,\phi'$;
	+	$\frac{2}{2}.\frac{3}{3}.\frac{4}{4}.5.\frac{1}{2^4}\,\phi'$	
$\frac{2}{2}.\frac{3}{3}.\frac{4}{4}.\frac{5}{5}.1.\frac{1}{2^5}\,\phi^0$	+	$5.1.\frac{1}{2^5}\,\phi^0$	
	+	$\frac{4}{2}.5.1.\frac{1}{2^5}\,\phi^0$	
	+	$\frac{3}{2}.\frac{4}{3}.5.1.\frac{1}{2^5}\,\phi^0$	$= 1\,\phi^0.$
	+	$\frac{2}{2}.\frac{3}{3}.\frac{4}{4}.5.1.\frac{1}{2^5}\,\phi^0$	
	+	$\frac{2}{2}.\frac{3}{3}.\frac{4}{4}.\frac{5}{5}.1.\frac{1}{2^5}\,\phi^0$	

By introducing the denominators 2, 3, 4, 5 into the coefficients of the terms of the respective groups in descending order, the successive are converted into simultaneous measures.

Whatever be the order n of a primitive constant generator, its immediate product increases uniformly, or is simply accelerated, and its simultaneous is half its successive measure: the mediate product is duply [doubly] accelerated, and its simultaneous is one third its suc-

cessive measure; the bimediate product is triply accelerated, and its simultaneous is one fourth its successive measure; and according to the same law down to the product of the order zero, which closes the genesis by annihilating the successive measure.

In the tablet, under the two semi-units of time $\frac{1}{2}' . 1'_t$ and $\frac{1}{2}'' . 1'_t$, any coefficient expresses the amount of its term, considered as an *effect* produced in that *semi-unit* of time; while it also expresses the value of its term considered as a *cause*, to be measured by the effect it would produce in a *unit* of time. As all the increments of the same order are the same number of genetical steps below the *independent* primitive generator $1\,\phi^{v}$, the same factor of acceleration will appear in the coefficient of each; but as the different increments in the time $\frac{1}{2}'' . 1'_t$ arise from different *dependent* constant generators, their rate of acceleration is modified accordingly.

The triply accelerated increment $\frac{4}{6}\,\phi_1''$ produces the quadruply accelerated effect $4 . \frac{5}{16}\,\phi'$ in the time $\frac{1}{2}'' . 1'_t$, and one fourth of that amount (successive measure) in the time $\frac{1}{2}' . 1'_t$ of its own genesis: the increment $\frac{1}{6}\frac{2}{4}\,\phi''$, produced by $\frac{3}{4}\,\phi_1'''$ constant during $\frac{1}{2}'' . 1'_t$, is simply accelerated by means of this last-mentioned increment, while yet it is also triply accelerated under the primitive generator $1\,\phi^{\cdot\cdot}$, and therefore produces $\frac{1}{2} . \frac{12}{16} . 5\,\phi' = \frac{30}{16}\,\phi'$ in that time; and the increment $\frac{1}{2} . \frac{24}{8}\,\phi''$, produced by $\frac{6}{4}\,\phi'''$ (which is simply accelerated, being produced by $\frac{3}{2}\,\phi_1^{iv}$ constant) in the time $\frac{1}{2}'' . 1'_t$, is doubly accelerated under the dependent constant generator $1\,\phi_1^{iv}$, and at the same time triply accelerated under the independent constant generator $1\,\phi^{v}$: the last-named acceleration has operated during the time $\frac{1}{2}' . 1'_t$ through the increment $\frac{2}{2}\,\phi_1^{iv}$, and the former operates in the time $\frac{1}{2}'' . 1'_t$ through $2 . \frac{3}{4}\,\phi'''$ and $\frac{3}{2} . \frac{12}{8}\,\phi''$, and combination gives the amount $\frac{1}{2} . \frac{1}{3} . 2 . 3 . 4 . 5 . \frac{1}{16}\,\phi' = \frac{30}{16}\,\phi'$ in the time $\frac{1}{2}'' . 1'_t$.

(12.) The determination of the values of m, m', m'', m''' establishes the successive series of generating powers $1\,\phi^{v}$, $2\,\phi^{iv}$, $3\,\phi'''$, $4\,\phi''$, $5\,\phi'$, $1\,\phi^{0}$, for the unit of time $1'_t$; and now it is easy to deduce their measures for the time $x\,1_t$. Recollecting that each preceding term generates the succeeding one during the time of its own genesis, and will generate twice, thrice, etc. that amount during the equal time afterwards, we say that

The constant primitive $1\,\phi^{v}$ of the fifth order generates uniformly $2\,\phi^{iv}$ in the unit of time 1_t, and therefore $2x\,\phi^{iv}$ in the time $x\,1_t$.

The immediately generated power of the fourth order $2\,x\,\phi^{IV}$, become constant at the expiration of the time $x\,1_t$, generates $2\,.\,3\,x^2\,\phi'''$ in the subsequent time $x\,1_t$, and therefore $3\,x^2\,\phi'''$ in the time $x\,1_t$ of its own genesis.

The mediately generated power of the third order $3\,x^2\,\phi'''$, constant at the expiration of the time $x\,1_t$, generates $3\,.\,4\,x^3\,\phi''$ in the subsequent time $x\,1_t$, and therefore $4\,x^3\,\phi''$ in the time $x\,1_t$ of its own genesis.

The bimediately generated power of the second order $4\,x^3\,\phi''$, become constant at the expiration of the time $x\,1_t$, generates $4\,.\,5\,x^4\,\phi'$ in the subsequent time $x\,1_t$, and therefore $5\,x^4\,\phi'$ in the time $x\,1_t$ of its own genesis.

The trimediately generated power of the first order $5\,x^4\,\phi'$, become constant at the expiration of the time $x\,1_t$, would generate $5\,x^5\,\phi^0$ in the subsequent time $x\,1_t$, and therefore actually does generate $1\,x^5\,\phi^0$ in the time $x\,1_t$ of its own genesis.

The successive series for the time $x\,1_t$ is therefore $1\,\phi^V$, $2\,x\,\phi^{IV}$, $3\,x^2\,\phi'''$, $4\,x^3\,\phi''$, $5\,x^4\,\phi'$, $1\,x^5\,\phi^0$; and it is evident, without further showing, that the corresponding simultaneous series is $1\,\phi^V$, $1\,x\,\phi^V$, $1\,x^2\,\phi'''$, $1\,x^3\,\phi''$, $1\,x^4\,\phi'$, $1\,x^5\,\phi^0$.

The successive series of powers being simultaneously in existence at the expiration of the time $x\,1_t$, it is finally necessary to investigate their complete result for the additional time $h\,1_t$, that is, for the whole time $(x + h)\,1_t$.

The *primitive* $1\,\phi$, having generated the final result $1\,x^5\,\phi^0$ in the past time $x\,1_t$, will generate the final result $1\,h^5\,\phi^0$ in the future time $h\,1_t$.

The *immediate* $2\,x\,\phi^{IV}$, generated in the past time $x\,1_t$, and become a constant generator, will generate $2\,.\,3\,x\,h\,\phi'''$ in the future time $h\,1_t$; which $2\,.\,3\,x\,h\,\phi'''$ would generate $2\,.\,3\,.\,4\,x\,h^2\,\phi''$ in a subsequent time $h\,1_t$, and therefore actually does generate $\frac{2\,.\,3\,.\,4}{1\,.\,2}\,x\,h^2\,\phi''$ in the time $h\,1_t$ of its own genesis: this $3\,.\,4\,x\,h^2\,\phi''$ would generate $3\,.\,4\,.\,5\,x\,h^3\,\phi'$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{3\,.\,4\,.\,5}{3}\,x\,h^3\,\phi'$ in the time $h\,1_t$ of its own genesis; and this $4\,.\,5\,x\,h^3\,\phi'$ would generate $4\,.\,5\,x\,h^4\,\phi^0$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{4\,.\,5}{4}\,x\,h^4\,\phi^0$ in the time $h\,1_t$ of its own genesis.

The *mediate* $3\,x^2\,\phi'''$, generated in the past time $x\,1_t$, and become a constant generator, will generate $3.4\,x^2\,h\,\phi''$ in the future time $h\,1_t$; which $3.4\,x^2\,h\,\phi''$ would generate $3.4.5\,x^2\,h^2\,\phi'$ in a subsequent time $h\,1_t$, and therefore actually does generate $\frac{3.4.5}{1.2}x^2h^2\phi'$ in the time $h\,1_t$ of its own genesis; and this $\frac{3.4.5}{1.2}\,x^2\,h^2\,\phi'$ would generate $\frac{3.4.5}{1.2}\,x^2\,h^3\,\phi^0$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{3.4.5}{1.2.3}\,x^2\,h^3\,\phi^0$ in the time $h\,1_t$ of its own genesis.

The *bimediate* $4\,x^3\,\phi''$, generated in the past time $x\,1_t$, and become a constant generator, will generate $4.5\,x^3\,h\,\phi'$ in the future time $h\,1_t$; while $4.5\,x^3\,h\,\phi'$ would generate $4.5\,x^3\,h^2\,\phi^0$ in the subsequent time $h\,1_t$, and therefore actually does generate $\frac{4.5}{1.2}\,x^3\,h^2$ in the time of its own genesis in $h\,1_t$.

The *trimediate* $5\,x^4\,\phi'$, generated in the past time $x\,1_t$, and become a constant generator, will generate $5\,x^4\,h\,\phi^0$ in the future time $h\,1_t$.

The *quatrimediate* $1\,x^5\,\phi^0$, generated in the past time $x\,1_t$, is a non-generator; and the final results make up the tablet:

$x\,1_t$: $\overbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}^{h\,1_t.}$

$1\,\phi^{\mathrm{v}}$; $\frac{1.2}{1}\,h\,\phi^{\mathrm{iv}}$, $\frac{1.2.3}{1.2}\,h^2\,\phi'''$, $\frac{1.2.3.4}{1.2.3}\,h^3\,\phi''$, $\frac{1.2.3.4.5}{1.2.3.4}\,h^4\,\phi'$, $\frac{1.2.3.4.5.1}{1.2.3.4.5}\,h^5\,\phi^0$.

$2\,x\,\phi^{\mathrm{iv}}$; $\frac{2.3}{1}\,x\,h\,\phi'''$, $\frac{2.3.4}{1.2}\,x\,h^2\,\phi''$, $\frac{2.3.4.5}{1.2.3}\,x\,h^3\,\phi'$, $\frac{2.3.4.5.1}{1.2.3.4}\,x\,h^4\,\phi^0$.

$3\,x^2\,\phi'''$; $\frac{3.4}{1}\,x^2\,h\,\phi''$, $\frac{3.4.5}{1.2}\,x^2\,h^2\,\phi'$, $\frac{3.4.5.1}{1.2.3}\,x^2\,h^3\,\phi^0$.

$4\,x^3\,\phi''$; $\frac{4.5}{1}\,x^3\,h\,\phi'$, $\frac{4.5.1}{1.2}\,x^3\,h^2\,\phi^0$.

$5\,x^4\,\phi'$; $\frac{5.1}{1}\,x^4\,h\,\phi^0$.

$1\,x^5\,\phi^0$.

The final result is

$$(1\,x^5+5\,x^4\,h+10\,x^3\,h^2+10\,x^2\,h^3+5\,x\,h^4+1\,h^5)\,\phi^0=(x+h)^5\,\phi^0,$$

for the time $(x+h)\,1_t$. If $x=h=1$, the series expresses the development of $(1+1)^5\,\phi^0 = 2^5\,\phi^0 = 32\,\phi^0$ for the time $2\,.\,1_t$.

(13.) To pass from the development of $(x+h)^5$ to that of $(x-h)^5$, all the genetical operations during the time $h\,1_t$ must be reversed, or performed in the opposite direction in space; whence the tablet becomes

$x\,1_t$: $\overbrace{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}^{h\,1_t.}$

$$1\,\phi^v \;;-\frac{1.2}{1}h\,\phi^{iv},+\frac{1.2.3}{1.2}h^2\,\phi''',-\frac{1.2.3.4}{1.2.3}h^3\,\phi'',+\frac{1.2.3.4.5}{1.2.3.4}h^4\,\phi',-\frac{1.2.3.4.5.1}{1.2.3.4.5}h^5\,\phi^0=-1\,h^5\,\phi^0.$$

$$2\,x\,\phi^{iv}\;;-\frac{2.3}{1}x\,h\,\phi''',+\frac{2.3.4}{1.2}x\,h^2\,\phi'',-\frac{2.3.4.5}{1.2.3}x\,h^3\,\phi',+\frac{2.3.4.5.1}{1.2.3.4}x\,h^4\,\phi^0=+5\,x\,h^4\,\phi^0.$$

$$3\,x^2\,\phi''' \;;-\frac{3.4}{1}x^2\,h\,\phi'',+\frac{3.4.5}{1.2}x^2\,h^2\,\phi',-\frac{3.4.5.1}{1.2.3}x^2\,h^3\,\phi^0=-10\,x^2\,h^3\,\phi^0.$$

$$4\,x^3\,\phi'' \;;-\frac{4.5}{1}x^3\,h\,\phi',+\frac{4.5.1}{1.2}x^3\,h^2\,\phi^0=+10\,x^3\,h^2\,\phi^0.$$

$$5\,x^4\,\phi' \;;-\frac{5.1}{1}x^4\,h\,\phi^0=-5\,x^4\,h\,\phi^0.$$

$$1\,x^5\,\phi^0.$$

The final result is

$$(1\,x^5-5\,x^4\,h+10\,x^3\,h^2-10\,x^2\,h^3+5\,x\,h^4-1\,h^5)\,\phi^0=(x-h)^5\,\phi^0,$$

for the time $(x-h)\,1_t$. If $x=h=1$, the series expresses the development of $(1-1)^5=0$ for the time $(1-1)\,1_t$.

3. Vital Statistics. By E. B. Elliott of Boston.

A. Tables of Prussian Mortality, interpolated for Annual Intervals of Age; accompanied with Formulæ and Process for Construction.

B. Discussion of Certain Methods for converting Ratios of Deaths to Population, within given Intervals of Age, into the Logarithm of the Probability that one living at the Earlier Age will attain the Later; with Illustrations from English and Prussian Data.

C. Process for deducing accurate Average Duration of Life, present Value of Life-Annuities, and other useful Tables involving Life-Contingencies, from Returns of Population and Deaths, without the Intervention of a General Interpolation.

The mortality and accompanying tables, to which the attention of the Association is called, comprise portions of a series of tables that have been and are being prepared, for the New England Mutual Life Insurance Company of Boston, from official returns of the British, Swedish, Prussian, and Belgian governments, and from such reliable American statistics as are obtainable.

In several of the United States of America the decennial enumeration of the numbers and ages of the living effected for the General Government have been quite accurate and reliable, while the only official *mortality* returns (viz. those ordered in connection with the last census, 1850) are inaccurate and deficient. In Massachusetts, since its Registration Act of 1849, certain districts have furnished valuable and satisfactory information respecting the numbers and ages of the dying; but from the published abstracts it has been impossible to separate imperfect from reliable data. In the yet unpublished abstracts of the returns for 1855 an improvement is being effected, under the direction of the present Secretary of State, which, although augmenting somewhat the expense, will afford fit material for the construction of a Life-Table that shall satisfactorily represent the rates of mortality prevailing among the inhabitants of the larger part of the Commonwealth.

The leading paper (A) presents a new Life-Table, complete for annual intervals of age, and calculated from over a million (1,197,407)

of observations regarding the ages of the dying, in a population of fifteen millions (14,928,501), and in a community where observations on vital statistics, for many years, are believed to have been made with care and accuracy. It adds *one* to the very limited list of National Life-Tables.

The remaining papers (B and C) are devoted to the discussion of certain methods for converting rates of mortality for different intervals of age into probability of living; and to the presentation of *abridged methods* for calculating, at certain ages, accurate tables of practical value, involving life-contingencies, accompanied with simple rules for determining any required value intermediate.

A. Tables of Prussian Mortality, interpolated for Annual Intervals of Age; accompanied with Formulæ and Process for Construction.

The data from which the following tables have been calculated were obtained from documents sent by Mr. Hoffman of Berlin to the English Ministry of Foreign Affairs, and published in the Sixth Annual Report of the Registrar-General in England.

Population of Prussia, Civil and Military (exclusive of Neufchatel).*

At the end of the year 1834, 13,509,927.
" " 1837, 14,098,125.
" " 1840, 14,928,501.

The documents above mentioned give no statistics of immigration or emigration.

The increase of population during the three years 1838, '39, '40, was 830,376.

The excess of births over deaths during the same three years was 486,937.

Leaving 343,439, which is 41.36 per cent of the total increase of population, unaccounted for by excess of births over deaths.

* "The population of Neufchatel, not included in the above, was 59,448 in 1837, 52,223 in 1825."

POPULATION OF PRUSSIA AT THE END OF THE YEAR 1840, CLASSED ACCORDING TO AGE AND SEX.

Ages.	Males.	Females.	Males.	Females.	Ages.
0 – 5	1,134,413	1,114,871			
5 – 7	370,740	336,429	2,603,699	2,550,022	0 – 14
7 – 14	1,098,546	1,068,722			
14 – 16	344,179	331,039			14 – 16
16 – 20	586,059				
20 – 25	692,704				
25 – 32	777,183		3,238,434	3,253,643	16 – 45
32 – 39	646,122				
39 – 45	536,366				
45 – 60	816,726	881,280			45 – 60
60 and upwards,	445,544	463,935			60 and upwards.
All Ages,	7,448,582	7,479,919			

Assuming the distribution of the (3,253,643) females for the several intervals between the ages 16 and 45 to be proportioned to the distribution of (3,238,434) the corresponding number of males, we have

Ages.	Females.
16 – 20	588,812
20 – 25	695,957
25 – 32	780,833
32 – 39	649,156
39 – 45	538,885
Total, 16 – 45	3,253,643

Hence the following

NUMBERS AND AGES OF THE POPULATION OF PRUSSIA AT THE END OF THE YEAR 1840.

Ages.	Persons.
0 – 5	2,249.284
5 – 7	737,169
7 – 14	2,167,268
14 – 16	675,218
16 – 20	1,174,871
20 – 25	1,388,661
25 – 32	1,558,016
32 – 39	1,295.278
39 – 45	1,075,251
45 – 60	1,698,006
60 and upwards,	909,479
All Ages,	14,928,501

We wish to distribute the population from ages 25 to 45, from 45 to

60, and from 60 upwards in quinquennial or decennial periods, to correspond with the ages of the dying as presented in the mortality returns.

We first determine the quinquennial distribution between ages 25 and 45.

Let $P_{x/y}$ represent the population between ages x and y, or the numbers living under age y, *less* the numbers living under age x.

Then $P_{16/20} = 1{,}174{,}871$
$P_{16/25} = 2{,}563{,}532$
$P_{16/32} = 4{,}121{,}548$
$P_{16/39} = 5{,}416{,}826$
$P_{16/45} = 6{,}492{,}077$
$P_{16/60} = 8{,}190{,}083$

Assume $P_{16/x} = P_{16/a}\frac{x-b\,.\,x-c}{a-b\,.\,a-c} + P_{16/b}\frac{x-a\,.\,x-c}{b-a\,.\,b-c} + P_{16/c}\frac{x-a\,.\,x-b}{c-a\,.\,c-b}$

Let $a = 20$, $b = 25$, $c = 32$; then will $P_{16/30} = 3{,}722{,}366$.

Let $a = 25$, $b = 32$, $c = 39$; then will $P_{16/30} = 3{,}703{,}211$, and $P_{16/35} = 4{,}708{,}839$.

Let $a = 32$, $b = 39$, $c = 45$; then will $P_{16/35} = 4{,}682{,}050$, and $P_{16/40} = 5{,}598{,}277$.

Let $a = 39$, $b = 45$, $c = 60$; then will $P_{16/40} = 5{,}611{,}751$.

Taking the arithmetical mean of the above duplicate results, we have

$P_{16/30} = 3{,}712{,}789$
$P_{16/35} = 4{,}695{,}445$
$P_{16/40} = 5{,}605{,}014$

Hence $P_{25/30} = 1{,}149{,}257$
$P_{30/35} = 982{,}656$
$P_{35/40} = 909{,}569$
$P_{40/45} = 887{,}063$

which results cannot vary materially from the actual distribution.

The following Table gives the distribution of the population of Prussia between ages 45 and 60 (1,698,006); and of the population from age 60 upwards, according to the corresponding proportional distribution of the numbers of the population of the Northwestern Division of England (the Eighth of the eleven Districts into which England and Wales are divided in the Reports of the Registrar-General).

Ages.	Distribution of Prussian Population over age 45.
45 – 55	1,257,322
55 – 60	440,684
60 – 65	353,657
65 – 75	398,925
75 – 85	137,188
85 – 95	18,638
95 and over,	1,026
45 and over,	2,607,485

NUMBERS AND AGES OF THE POPULATION OF THE NORTHWESTERN DIVISION (ENG.) IN 1841, ACCORDING TO WHICH THE ABOVE DISTRIBUTION WAS MADE. — (9th Rep. Reg.-Gen.)

Ages.	Northwestern Division (Eng.), 1841. Numbers and Ages of the Living above Age 45.
45 - 55	151,064
55 - 60	52,947
60 - 65	39,656
65 - 75	44,732
75 - 85	15,383
85 - 95	2,095
95 and over,	115
45 and over,	305,992

The numbers living above age 15 in the Northwestern Division (England) were grouped, with reference to age, only in decennial classes.

By assuming the algebraic equation,

$$P_{55/x} = P_{55/45} \cdot \frac{x-55 \,.\, x-65 \,.\, x-75}{45-55 \,.\, 45-65 \,.\, 45-75} + P_{55/65} \cdot \frac{x-45 \,.\, x-55 \,.\, x-75}{65-45 \,.\, 65-55 \,.\, 65-75} + P_{55/75} \cdot \frac{x-45 \,.\, x-55 \,.\, x-65}{75-45 \,.\, 75-55 \,.\, 75-65}$$

a close approximation to the probable number of persons living between ages 55 and 60 (52,947) and between ages 60 and 65 (39,656) resulted.

$P_{55/x}$ represents the number of persons reported living under age x, *less* the number living under age 55.

We remark that $P_{55/45}$ is essentially negative.

The population of the Division, as returned for the night of June 6 - 7, 1841, was two millions (2,098,820), being one eighth of the entire population of England and Wales (15,914,148) at that date. The counties of Cheshire and Lancashire constitute this Division. The latter county includes the densely populous and unhealthy district of Liverpool.

The ratios of deaths to population for the intervals from age 45 to 60, and from age 60 upwards, more closely approximated the corresponding ratios for Prussia, than did those of any other large community concerning which reliable population and mortality statistics were to be obtained.

TABLE COMPARING RATIOS OF THE ANNUAL NUMBER OF DEATHS TO THE NUMBERS LIVING IN CERTAIN COMMUNITIES FROM AGE 45 TO 60, AND FROM AGE 60 TO EXTREME OLD AGE.

	Ages 45 - 60.	Ages 60 and upwards.
Prussia.		
Deaths, 1839, '40, '41, / Population, 1840,	.024	.088
Northwestern Division (England).		
Deaths, seven years, 1838 - 44, / Population, middle, 1841,	.023	.079+
Sweden.		
Deaths, twenty years, 1821 - 40, / Population, mean of 1820, '30, '40,	.021	.079—
Belgium.		
Deaths, nine years, 1842 - 50, / Population, October 15, 1856,	.020	.073
England and Wales.		
1841,	.019	.069

A comparison of the distribution of the numbers of the living in Prussia in these intervals of age according to that of the Northwestern Division (Eng.), with a distribution of the same numbers according to the mean of the corresponding distribution of equal numbers of the populations of England in 1841 and of Belgium in 1846, would give the following results.

DISTRIBUTION OF THE POPULATION OF PRUSSIA ACCORDING TO

Ages.	The Mean of Equal Numbers in England and Belgium.	The Northwestern Division (England).
45 - 55	1,285,567	1,257,322
55 - 60	412,439	440,684
45 - 60	1,698,006	1,698,006
60 - 65	330,425	353,657
65 - 75	398,646	398,925
75 - 85	155,077	137,188
85 and over,	25,331	19,709
60 and over,	909,479	909,479
45 and over,	2,607,485	2,607,485

The distribution according to the English and Belgian facts would give larger numbers after about age 75, in the resulting Life-Table.

The distribution according to that of the Northwestern Division was adopted as the best representation of the probable corresponding distribution of the population of Prussia, within the intervals of age above mentioned. Hence the following Table.

Deaths, Population, Mortality, and Logarithms of the Probability of Living in Prussia.

The Numbers of the Living between ages 45 *and* 60, *and from* 60 *to extreme old age are distributed according to corresponding proportional distributions of the numbers of the population of the Counties of Cheshire and Lancashire (Northwestern Division), in England, in* 1841.

	Deaths.	Population.	Mortality.	Logarithms of Probabilities of Surviving each Interval.	
	Aggregate Numbers and Ages of the Dying during the Three Years 1839, '40, '41.	Numbers and Ages of the Living at the End of the Year 1840.	Ratios of the Average Annual Numbers of the Dying during the Three Years 1839, '40, '41, to the Numbers of the Living computed with reference to the Middle of 1840.	Duplicate Values, each deduced from two consecutive Ratios in the Column of Mortality.	Values derived from Comparison of the Duplicates.
Ages. x, y.	$D_{0/y} - D_{0/x}$	$P_{0/y} - P_{0/x}$	$\frac{D_{x/y}}{P_{x/y}} \cdot C$	$\lambda p_{0/y} - \lambda p_{0/x}$	
	$D_{x/y}$	$P_{x/y}$	$M_{x/y}$	$\lambda p_{x/y}$	
0 – 1	310,527	2,249,284	.0802238		
1 – 3	162,356				
3 – 5	62,734				
5 – 7	33,272	737,169	.0152056	—.013106	—.013155
				—.013201	
7 – 14	27,156	2,167,268	.0077790	—.023480	—.023557
				—.023628	
14 – 20	22,887	1,850,089	.0062978	—.016399	—.016416
				—.016432	
20 – 25	34,585	1,388,661	.0089397	—.019433	—.019425
				—.019418	
25 – 30	36,849	1,149,257	.0096939	—.021057	—.021058
				—.021059	
30 – 35	31,594	982,656	.0108317	—.023533	—.023537
				—.023542	
35 – 40	35,579	909,569	.0131780	—.028646	—.028637
				—.028630	
40 – 45	38,094	887,063	.0144675	—.031434	—.031449
				—.031464	
45 – 55	78,503	1,257,322	.0210345	—.092155	—.092322
				—.092527	
55 – 60	46,704	440,684	.0357042	—.077947	—.077981
				—.078021	
60 – 65	58,576	353,657	.0557995	—.122543	—.122189
				—.121891	
65 – 75	107,653	398,925	.0909134	—.424020	—.415608
				—.408584	
75 – 85	61,697	137,188	.1515098	—.716433	—.722021
				—.730677	
85 and upwards	15,572	19,709	.2661784		
Total,	1,197,407	14,928,501			

$C = \frac{1}{3} \cdot \frac{14928501}{14770727}$ = Population of Prussia, as returned for the end of the year 1840.

= Population of Prussia, estimated for the middle of the year 1840, from the numbers returned as living at the end of 1834, 1837, and 1840.

It will be observed that the values derived from comparison of the duplicate logarithms, and which have been adopted in constructing the Interpolated and other Tables, are not in all cases arithmetical means. The difference is of little moment, but there is no sufficient reason for preferring the former.

LOGARITHMS OF THE PROBABILITY OF SURVIVING,

Computed from the Returns of the Numbers of the Living under Age 5; *and of the Numbers of the Dying annually under* 1 *Year of Age, over* 1 *and under* 3, *over* 3 *and under* 5.

Ages.	$\lambda\, p_{x/y}$.
0 – 1	— .082920
1 – 3	— .051670
3 – 5	— .022522

The successive addition of the logarithms of the probabilities of surviving the consecutive intervals of age to 5.001688, the logarithm assumed for the proportional numbers born alive, gives the following

TABLE OF THE LOGARITHMS OF THE PROPORTIONS, AND THE PROPORTIONS OF PERSONS BORN ALIVE AND SURVIVING CERTAIN AGES IN PRUSSIA, ACCORDING TO THE CALCULATED LAW OF MORTALITY.

Deaths, 1839, '40, '41.

Population computed with reference to middle of 1840.

Distribution of Population above Age 45, *Northwestern Division* (*Eng.*).

Age.	Survivors.	
	Logarithms.	Persons.
	$\lambda\, L_x$	L_x
0	5.001688	100,389
1	4.918768	82,941
3	4.867098	73,637
5	4.844576	69,916
14	4.807864	64,249
25	4.772023	59,159
35	4.727428	53,386
45	4.667342	46,488
55	4.575020	37,585
65	4.374850	23,706
75	3.959242	9,104.2
85	3.237221	1,726.7
95	1.982879	96.1
105	— 1.803755	.636

The values opposite ages 95 and 105 were computed from the logarithms of the numbers surviving at ages 65, 75, and 85, by the exponential formula,

$$\lambda L_x = \Phi_x = \Phi_{65} + (\Phi_{75} - \Phi_{65}) \frac{q^{x-65} - 1}{q^{75-65} - 1};$$

in which

$$q^{75-65} \text{ (or } q^{10}) = \frac{\Phi_{85} - \Phi_{75}}{\Phi_{75} - \Phi_{65}}.$$

These values were adopted as bases for the construction of the accompanying Life-Table *interpolated* for annual intervals of age; and also for computing by *abridged methods* certain practical life-contingency tables.

Before presenting this table and these methods, we will state some of the principles which underlie, and indicate the process by which ratios of the numbers of the dying to the numbers of the living, during the several intervals of age, have been converted into logarithms of the probabilities that one living at the earlier age will attain the later.

Whenever, in any community, the intensity of mortality at each age, or the ratio of the numbers momentarily dying during each *minute* interval of age to the numbers then living within the same interval, has been *constant* for a period of time equal to the difference between the specified age and the extreme of old age, an *invariable law of mortality* is said to prevail in that community.

The law of human mortality is seldom strictly invariable. It fluctuates within *certain limits*, not only with different communities and localities, but in the same community during successive periods, and in the same localities. The habits, occupations, and social condition of the members of the community remaining unchanged, the larger their numbers the *narrower* these limits. It is within the province of the vital statistician to determine, not merely an average of the rates of mortality prevailing in a community, but also the sensible limits within which the rates fluctuate.

Our present inquiries have reference to the determination of a law of mortality which shall satisfactorily represent the average of the rates prevailing among the inhabitants of a populous state, with fixed geographical boundaries; and in which the numbers of the inhabitants vary with births and with deaths, with immigration and with emigration.

If, in a large community, varying with births, deaths, and migrations, but in which the numbers of the population have not been subject to sudden and irregular change, the number of the dying during a given year or period of time between ages not very remote be divided by the number of the living between the same ages at the middle of that period of time, the quotient resulting from the division has generally been assumed closely to approximate the quotient that would have resulted had the numbers of the population within the limits of these ages been *stationary;* that is, assuming an invariable law of mortality, had the numbers of the population for each minute interval of age within the limits of these ages remained constant during that period, and unaffected by either immigration or emigration.

The errors involved in this assumption are of small moment compared with probable errors of observation, and vanish when the intervals of age are taken exceedingly minute, and where the excess or deficiency of the deaths in the former half of the period of time, with reference to half the deaths of the entire period, is exactly counterbalanced by a corresponding deficiency or excess of the deaths in the latter half of that period of time.

We adopt this hypothesis, and assume that each of the ratios in the column headed Mortality is identical with that which would have resulted had the population of Prussia within the limits of the ages been stationary for a period of years equal to the specified interval; and we also assume the accuracy of the Prussian mortality and population returns.

From these ratios we now proceed to determine duplicate logarithms of the probability that one surviving the earlier age in each interval will attain the later.

Let $P_{0/x}$ = the number living under age x, in a stationary population, in which the same law of mortality prevails as in Prussia.

$D_{0/x}$ = the number of annual deaths under age x in the stationary population.

l_0 = the number born alive each *moment of time*, in the stationary population.

l_x = the number surviving x years, out of (l_0) the momentary number of births.

$p_{a/b} = \frac{l_b}{l_a}$ = the probability that one surviving the earlier age (a) will attain the later (b).

$\delta_{0/x} = l_0 - l_x$ = the number dying in x years out of (l_0) the momentary number of births.

In a stationary population

$$\Gamma_{0/x} = \frac{\delta_{0/x}}{dx},$$

and

$$dP_{0/x} = l_x;$$

therefore,

$$P_{0/x} = \int (l_0 - \delta_{0/x}) = \frac{x \cdot l_0}{dx} - \int \delta_{0/x}.$$

But $M_{a/b}$, the ratio of the average annual number of deaths in Prussia between ages a and b to the number of the living between these ages, computed with reference to the middle of the period in which the deaths occur, equals $\frac{D_{a/b} = D_{0/b} - D_{0/a}}{P_{a/b} = P_{0/b} - P_{0/a}}$.

Assume $\delta_{0/x} = Qx + Rx^2$, Q and R being unknown, and independent of the variable x.

Then

$$D_{0/x} = \frac{Qx + Rx^2}{dx},$$

and

$$\int \delta_{0/x} = \left(Q\frac{x^2}{2} + R\frac{x^3}{3}\right)\frac{1}{dx}.$$

Hence

$$M_{a/b}\left(\text{which} = \frac{D_{a/b}}{P_{a/b}} = \frac{D_{0/b} - D_{0/a}}{P_{0/b} - P_{0/a}}\right) = \frac{Q\overline{b-a} + R\overline{b^2-a^2}}{l_0\overline{b-a} - Q\frac{b^2-a^2}{2} - R\frac{b^3-a^3}{3}}$$

$$= \frac{Q + R\overline{b+a}}{l_0 - Q\frac{b+a}{2} - R\frac{b^2+ab+a^2}{3}},$$

and

$$M_{b/c} = \frac{Q + R\overline{c+b}}{l_0 - Q\frac{c+b}{2} - R\frac{c^2+bc+b^2}{3}}.$$

So also,

$$\lambda p_{a/b} \text{ (which} = \lambda \frac{l_b}{l_a} = \lambda \frac{l_0 - \delta_{0/b}}{l_0 - \delta_{0/a}}) = \lambda \frac{l_0 - Q\,b - R\,b^2}{l_0 - Q\,a - R\,a^2},$$

and

$$\lambda p_{b/c} = \lambda \frac{l_0 - Q\,c - R\,c^2}{l_0 - Q\,b - R\,b^2}.$$

Given $M_{a/b}$ and $M_{b/c}$, required $\lambda p_{a/b}$ and $\lambda p_{b/c}$.

First determine values for Q and R; the values of $\lambda p_{a/b}$ and $\lambda p_{b/c}$ are then readily found.

$$Q = \frac{\gamma' M_{a/b} - \beta' M_{b/c}}{\gamma' \beta - \beta' \gamma} \cdot l_0,$$

and

$$R = \frac{\gamma M_{a/b} - \beta M_{b/c}}{\gamma \beta' - \beta \gamma'} \cdot l_0;$$

in which

$$\beta = 1 + \frac{(b + a) M_{a/b}}{2};$$

$$\beta' = b + a + \frac{(b^2 + b\,a + a^2) M_{a/b}}{3};$$

$$\gamma = 1 + \frac{(c + b) M_{b/c}}{2};$$

$$\gamma' = c + b + \frac{(c^2 + c\,b + b^2) M_{b/c}}{3}.$$

The reduction may be simplified by letting $l_0 = 1$, and by the use of addition and subtraction logarithms.

In like manner, from $M_{b/c}$ and $M_{c/d}$ obtain $\lambda p_{b/c}$ and $\lambda p_{c/d}$; and so on for all intervals of age which the returns give.

We thus obtain *duplicate* values for the logarithms of the probabilities of surviving all the intervals specified except two. For the first and the last interval we have but single values. We may, without material error, adopt for the true probability the mean of these duplicate results.

It will be observed that the conversion, in each of these cases, is made for the *entire* interval, not, as is more frequent, for the *middle*

year of the interval. We are thus enabled, without the intervention of a general interpolation, to compute directly the number surviving at certain ages in the resulting life-table, out of a specified number born alive.

Usually the conversion is from a *single* ratio, based upon the assumption of a uniform distribution of deaths throughout the interval. By the present method, however, the conversion is effected, taking into account the actual or variable distribution of deaths, from *three* consecutive ratios, one preceding and another following the interval. A comparison of the relative accuracy and simplicity of several methods for effecting the conversion will be given on a following page.

We now proceed to indicate methods for obtaining *probabilities of surviving from birth to ages one, three, and five.*

We have the average annual number of deaths in Prussia under the ages of one, three, and five ($D_{0/1}$, $D_{0/3}$, $D_{0/5}$), for the period of the three years 1839, '40, '41; and the population under the age of five ($P_{0/5}$) at the end of the middle year of the period (end of 1840); also the *ratio* $\left(\frac{1}{v}\right)$ of the annual increase in the number of births deduced from the numbers registered for each of the six years 1836–41. The average annual number of deaths for the three years 1839, '40, '41 we shall consider identical with the number of deaths for the year 1840.

From the following, it would appear that the *accurate* number of those born alive cannot be obtained directly from official reports, because of probable deficiencies in registration. If the numbers of the living and of the dying at the earlier ages have been accurately observed and returned, if the numbers at these ages have been but little affected by immigration and emigration, and if the ratio of annual increase in the number of births can be obtained, a close approximation to the actual number of those born alive may be computed.

Let l_0 be the number of those momentarily born alive in Prussia at the time for which the census was taken (end of 1840).

$\frac{1}{v} = \left(\frac{\text{births 1839, '40, '41}}{\text{births 1836, '37, '38}}\right)^{\frac{1}{3}} = 1.01545$, the ratio of the annual increase in the number of births estimated from those registered for each of the six years 1836–41.

$\lambda \frac{1}{v} = .0066586$, the logarithm of this ratio.

Let $\delta_{0,x}$ be the number that died before attaining the age of x years (according to the prevailing law of mortality) out of (l_0) the number born alive in Prussia during the moment of time (end of 1840) that the enumeration of the living is supposed to have been made.

$v^x d\,\delta_{0/x}$ will express the number of those aged x years that died in Prussia during the supposed moment of enumeration.

$$\int_0^x v^x d\,\delta_{0/x} \int_0^1 v^x = D_{0/x},$$

the annual number of deaths in Prussia under the age of x years, for the year ending with the census, i. e. for the year 1840.

$$v^x \int_0^x v^{-x} \int_0^x v^x d\,\delta_{0/x}$$

represents the total number that died in Prussia during the x years preceding the time of the enumeration of the living, out of the numbers born alive within that period. This expression obviously equals

$$v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}.$$

$$l_0 \int_0^x v^x$$

represents the number born alive during the x years preceding the time of the enumeration.

The numbers born alive within this period of x years, *less* the numbers dying within the period out of the numbers born alive, obviously represent the numbers of the living at the end of the period under the age of x years; immigration and emigration among those under age x being considered null.

$$P_{0/x} = l_0 \int_0^x v^x - v^x \int_0^x v^{-x} \int_0^x v^x d\,\delta_{0/x}$$

$$= l_0 \int_0^x v^x - v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}.$$

$$l_0 \int_0^1 v^x = L_0,$$

the numbers born alive during (1840) the year immediately preceding the time of enumeration.

Hence

$$L_0 \left(= l_0 \int_0^1 v^x\right) = \left\{P_{0/x} + v^x \int_0^x v^{-x} \int_0^x v^x \, d\, \delta_{0/x}\right\} \frac{\int_0^1 v^x}{\int_0^x v^x}$$

$$= \left\{P_{0/x} + v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}\right\} \frac{\int_0^1 v^x}{\int_0^x v^x}.$$

$$d\,x \int_0^x v^x = \frac{v^x - 1}{V};$$

in which V is the Napierian logarithm of v.

Let $x = 5$; then will

$$L_0 = \left\{P_{0/5} + \int_0^5 \frac{v^5 V}{v-1} \cdot \frac{D_{0/x}\, d\,x}{v^x}\right\} \frac{v-1}{v^5-1}.$$

To simplify, let

$$D'_{0/x}\, d\,x = \frac{v^{5-x} D_{0/x}}{\int_0^1 v^x} = \frac{v^5 V}{v-1} \cdot \frac{D_{0/x}\, d\,x}{v^x}.$$

Then

$$L_0 = \left\{P_{0/x} + \int_0^5 D'_{0/x}\, d\,x\right\} \frac{v-1}{v^5-1}.$$

The returns give

$D_{0/1} = 103{,}509$
$D_{0/3} = 157{,}628$
$D_{0/5} = 178{,}539$
} average annual deaths under ages one, three, and five.

$P_{0/5} = 2{,}249{,}284$ { population under age five at the end of the year 1840.

From these, and from $.0066586 \left(= \lambda \frac{1}{v}\right)$ the logarithm of the ratio of annual increase among registered births, we find

$$D'_{0/1} = 98{,}100,$$
$$D'_{0/3} = 154{,}043,$$
$$D'_{0/5} = 179{,}912.$$

Assume

$$D'_{0/x} = D'_{0/0}\,[=0] + x\,\theta + x \cdot \overline{x-1}\,\theta^2 + x \cdot \overline{x-1} \cdot \overline{x-3}\,\theta^3 + x \cdot \overline{x-1} \cdot \overline{x-3} \cdot \overline{x-5}\,R$$

$$= x\theta + (x^2 - x)\theta^2 + (x^3 - 4x^2 + 3x)\theta^3 + (x^4 - 9x^3 + 23x^2 - 15x)\,R.$$

$$\int_0^x D'_{0/x}\,dx = \frac{x^2}{2}\theta + \left(\frac{x^3}{3} - \frac{x^2}{2}\right)\theta^2 + \left(\frac{x^4}{4} - \frac{4x^3}{3} + \frac{3x^2}{2}\right)\theta^3$$
$$+ \left(\frac{x^5}{5} - \frac{9x^4}{4} + \frac{23x^3}{3} - \frac{15x^2}{2}\right)R$$
$$= \frac{x^2}{2}\left\{\theta + \frac{2x-3}{3}\theta^2 + \frac{(3x-16)x+18}{6}\theta^3 + \frac{[(12x-135)x+460]x-450}{30}R\right\}.$$

$$\frac{dD'_{0/x}}{dx} = \theta + (2x-1)\theta^2 + (3x^2 - 8x + 3)\theta^3 + (4x^3 - 27x^2 + 46x - 15)R.$$

$$\frac{d^2 D'_{0/x}}{(dx)^2} = 2\theta^2 + (6x-8)\theta^3 + (12x^2 - 54x + 46)R.$$

θ, θ^2, and θ^3 are the *divided differences* of the values $D_{0/0}$ $(= 0)$, $D_{0/1}$, $D_{0/3}$, and $D_{0/5}$; and R is indeterminate.

		Δ	θ	$\Delta\theta$	θ^2	$\Delta\theta^2$	θ^3
$D'_{0/0}$ =	0 000						
		98,100	98,100.				
$D'_{0/1}$ =	98,100			— 70,128.5	— 23,376.17		
		55,943	27,971.5			19,616.92	3,923.38
$D'_{0/3}$ =	154,043			— 15,037.0	— 3,759.25		
		25,869	12,934.5				
$D'_{0/5}$ =	179,912						

We observe that the divided differences of the first order are *positive*, and that they *diminish* as the age advances.

Required for R a value such that the *first* differential coefficients of the function assumed for $D'_{0/x}$ be *positive*. It would also be desirable, if possible, that the *second* differential coefficients, from birth to at least age five, be *negative*.

The latter is not possible for the entire period, with our present values for $D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$, if we assume but one arbitrary value (R). Our object, however, is sufficiently attained by taking, for R, a value such that for ages *three* and *five* the above conditions shall be observed.

That the first differential coefficients be *positive* for ages three and five, it is requisite that

$$R \begin{cases} < & 396.6 \\ > & -920.1; \end{cases}$$

that the second differential coefficients be *negative* for the same ages, it is requisite that

$$R > -939.8$$
$$< -520.6;$$

from which it appears that R should be *negative*, and that its value be

between — 920.1
and — 520.6

Let $R = -700$. We now have

$$\theta = 98{,}100$$
$$\theta^2 = -23{,}376.17$$
$$\theta^3 = 3{,}923.38$$
$$R = -700.$$

Hence

$$\int_0^5 D'_{0/x}\,dx \text{ (which } = \frac{25}{2}\theta + \frac{175}{6}\theta^2 + \frac{325}{12}\theta^3 - \frac{125}{12}R) = 657{,}995.$$

$$L_0 = \left\{P_{0/5} + \int_0^5 D'_{0/x}\,dx\right\}\frac{v-1}{v^5-1};$$

in which

$$\lambda\frac{v-1}{v_5-1} = \bar{1}.3142433,$$

and

$$P_{0/5} = 2{,}249{,}284;$$

therefore,

$$L_0 = 599{,}418.$$

By the above process the probable number born alive during the year 1840 is found to have been 599,418 instead of 562,394, the average of the numbers *registered* as born alive during each of the three years 1839, '40, '41; thereby indicating an annual deficiency in the registration of 37,024, or about 6.2 per cent of the probable number born.

In the above we have supposed the numbers of the dying and of the living at early ages accurately returned. If either be represented less than truth, the resulting correction would give still larger the probable number of births. Correction for deaths that escape registration, if any, would tend to reduce the probabilities of living.

Having found L_0 (which equals $\frac{v-1}{V}\cdot\frac{l_0}{dx}$), the annual number of births for the year 1840, we next seek values, corresponding to intervals of age 0 - 1, 1 - 3, and 3 - 5, for $D''_{0/x}$ (which equals $\frac{v-1}{V}\cdot\frac{d_{0/x}}{dx}$), the annual number of deaths in a stationary popula-

tion in which L_0 is the annual number of births; or the number that must die in x years, according to the law of mortality prevailing in Prussia, out of L_0, born alive.

$$v^x D'_{0/x} = \frac{v^5 V}{v-1} D_{0/x}$$

$$= \frac{v^5 V}{v-1} \int_0^x v^x \frac{d\,\delta_{0/x}}{dx} \cdot \frac{v-1}{V}$$

$$= \frac{v^5 V}{v-1} \int_0^x v^x\, d\, D''_{0/x}.$$

$$\therefore\ v^x\, d\, D''_{0/x} = \frac{v-1}{v^5 V} \cdot d\,(v^x D'_{0/x}).$$

But

$$d\,(v^x \cdot D'_{0/x}) = v^x \cdot d\, D'_{0/x} + D'_{0/x} \cdot d\, v^x = v^x\,(d\, D'_{0/x} + V D'_{0/x}\, dx);$$

$$\therefore\ d\, D''_{0/x} = (d\, D'_{0/x} + V D'_{0/x}\, dx) \frac{v-1}{v^5 V}.$$

Integrating,

$$D''_{0/x} = \frac{v-1}{v^5 V} D'_{0/x} + \frac{v-1}{v^5} \int_0^x D'_{0/x}\, dx.$$

v, V, $D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$ are already known; also θ, θ^2, and θ^3, and R in the expression

$$\int_0^x D'_{0/x}\, dx = \frac{x^2}{2} \left\{ \theta + \frac{2x-3}{3} \theta^2 + \frac{(3x-16)\,x + 18}{6} \theta^3 + \frac{[(12x-135)\,x + 460]\,x - 450}{30} R \right\}.$$

Substituting for x values 1, 3, and 5, we have

$$\int_0^1 D'_{0/x}\, dx = 55{,}899,$$

$$\int_0^3 D'_{0/x}\, dx = 323{,}335,$$

$$\int_0^5 D'_{0/x}\, dx = 657{,}995.$$

Therefore,

$$D''_{0/1} = 104{,}184,$$
$$D''_{0/3} = 159{,}735,$$
$$D''_{0/5} = 181{,}955.$$

$\lambda p_{0/x}$ (the logarithm of the probability that one born alive will survive x years) $= \lambda \dfrac{l_0 - \delta_{0/x}}{l_0} = \lambda \dfrac{L_0 - D''_{0/x}}{L_0}$.

Therefore,

$$\lambda p_{0/1} = \bar{1}.9170804 = \lambda .82619,$$
$$\lambda p_{0/3} = \bar{1}.8654097 = \lambda .73352,$$
$$\lambda p_{0/5} = \bar{1}.8428880 = \lambda .69645.$$

Hence of 100,000 born alive there will attain the age of

one year 82,619,
three years 73,352,
five years 69,645;

or of 100,389 born alive there will attain the age of

one year 82,941,
three years 73,637,
five years 69,916.

The latter results are those adopted in the accompanying interpolated and other tables. These tables, as first constructed, represented the probability of surviving five years from birth to be .69916, computed by a process less rigorous and satisfactory than the one just described. By assuming the same number surviving at age five (69,916) as in the original table, modification of the values for ages greater than five becomes unnecessary.

The logarithms of the numbers surviving certain ages out of 100,389 born alive may be continued for ages greater than five, by successively adding to 4.8445759 (the logarithm of the number surviving age five), the logarithms that have previously been determined for the probabilities of surviving the consecutive intervals.

The table will then be ready, either for a general interpolation of the numbers surviving each anniversary of birth, or for obtaining, by abridged methods, the accurate average duration of life, life annuities, annual premiums, single premiums, and other practical tables involving life contingencies, for certain ages, without the intervention of a general interpolation. Simple rules may also be added for computing from these periodical results any specified values intermediate.

The following is a brief method for finding *approximate* values for the probabilities of surviving the intervals from birth to ages one, three, and five, on the supposition of a probable deficiency in the registered number of births, and that the ratio between the numbers registered and the true numbers is constant.

The same interpretation of symbols is observed as in the last demonstration.

We already have

$$L_0 = l_0 \int_0^1 v^x = \frac{P_{0/5} + \int_0^5 D'_{0/x}\, dx}{\int_0^5 v^x} \int_0^1 v^x,$$

$$D'_{0/x}\, dx = \frac{v^{5-x} D_{0/x}}{\int_0^1 v^x},$$

and

$$D_{0/x} = \int_0^x v^x\, d\, \delta_{0/x} \int_0^1 v^x.$$

When the interval $(0-x)$ is not large, $x\, v^{\frac{x}{2}}$ is a close approximation to the value of $\int_0^x v^x\, dx$; hence the following approximate relations.

$$L_0 = \frac{l_0}{d\, x} v^{\frac{1}{2}} = \left\{ P_{0/5} + \int_0^5 D'_{0/x}\, dx \right\} \frac{v^{\frac{1}{2}}}{5\, v^{\frac{1}{2}}}.$$

$$D'_{0/x} = \frac{v^5}{v^{\frac{1}{2}}} \cdot \frac{D_{0/x}}{v^x}.$$

$$v^{\frac{1}{2}} \cdot \frac{d\, \delta_{0/x}}{d\, x} = \frac{d\, D_{0/x}}{v^x}.$$

Let us first seek an approximate value for L_0.

It is obvious that

$$\int_0^5 D'_{0/x}\, dx = \int_3^5 D'_{0/x}\, dx + \int_1^5 D'_{0/x}\, dx + \int_0 D'_{0/x}\, dx.$$

Assuming each term, in the right-hand member, to be the integral of the general term of an *equidifferent* progression, we have

$$\int_3^5 D'_{0/x}\, dx = \overline{5-3}\, \frac{D'_{0/5} + D_{0/3}}{2}.$$

$$\int_1^5 D'_{0/x}\, dx = \overline{3-1}\, \frac{D'_{0/3} + D'_{0/1}}{2}.$$

$$\int_0^1 D'_{0/x}\, dx = \overline{1-0}\, \frac{D'_{0/1}}{2}.$$

Therefore,

$$\int_0^5 D'_{0/x}\, dx = D'_{0/5} + 2\, D'_{0/3} + \tfrac{3}{2} D'_{0/1}.$$

Since

$$D'_{0/x} = \frac{v^5}{v^{\frac{1}{2}}} \cdot \frac{D_{0/x}}{v^x},$$

$D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$ equal respectively 98101, 154044, and 179913.

Therefore,

$$\int_0^5 D'_{0/x}\,dx = 635{,}152.$$

But

$$L_0 = \frac{P_{0/5} + \int_0^5 D'_{0/x}\,dx}{5v^2}$$

$$= \frac{2{,}249{,}284 + 635{,}152 = 2{,}884{,}436}{5v^2}$$

$$= 594{,}851.$$

594,851, the computed number of births for the year 1840 by this *approximate* method, is *less* by about three fourths of one per cent than 599,418, the corresponding number of births computed by the previous method.

Having found an approximate value for

$$v^{\frac{1}{2}} \cdot \frac{l_0}{dx} \text{ (or } L_0),$$

we next wish approximate values for

$$v^{\frac{1}{2}} \cdot \frac{\delta_{0/x}}{dx} \left(\text{or } \int_0^x \frac{d\,D_{0/x}}{v^x}\right),$$

corresponding to intervals of age 0 – 1, 0 – 3, and 0 – 5.

When the interval $b - a$ is small,

$$\int_a^b \frac{d\,D_{0/x}}{v^x} \text{ nearly equals } \frac{D_{0/b} - D_{0/a}}{v^{\frac{b+a}{2}}}, \text{ or } \frac{D_{a/b}}{v^{\frac{b+a}{2}}}.*$$

Hence the following approximations:

$$v^{\frac{1}{2}} \frac{\delta_{0/1}}{dx} = \frac{D_{0/1}}{v^{\frac{1}{2}}} = 104{,}306.$$

$$v^{\frac{1}{2}} \frac{\delta_{1/3}}{dx} = \frac{D_{1/3}}{v^2} = 55{,}804.$$

$$v^{\frac{1}{2}} \frac{\delta_{3/5}}{dx} = \frac{D_{/5}}{v^4} = 22{,}234.$$

$$\therefore\ v^{\frac{1}{2}} \frac{\delta_{0/1}}{dx} = 104{,}306.$$

$$v^{\frac{1}{2}} \frac{\delta_{0/3}}{dx} = 160{,}110.$$

$$v^{\frac{1}{2}} \frac{\delta_{0/5}}{dx} = 182{,}344.$$

* This approximation was adopted by Dr. Farr in constructing his Austrian Life-Table. — *Rep. Reg. Gen.*

Hence

$$p_{0/1}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/1}\, v^1}{dx}}{L_0}) = \lambda^{-1}\bar{1}.9162709 = .82465.$$

$$p_{0/3}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/3}\, v^3}{dx}}{L_0}) = \lambda^{-1}\bar{1}.8638226 = .73084.$$

$$p_{0/5}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/5}\, v^5}{dx}}{L_0}) = \lambda^{-1}\bar{1}.8410233 = .69346.$$

Then of 100,000 born alive there will be living at ages

(1) 82,456,
(3) 73,084,
(5) 69,346;

or assuming the number living at age five to be 69,916, the same as in accompanying tables, then out of 100,821 born alive there will be living at ages

(1) 83,143,
(3) 73,684,
(5) 69,916.

This table, joined with the interpolated for ages greater than five, gives for average future duration of life 36.51 years from birth, instead of 36.66, according to the values previously obtained, and adopted in the interpolated and other tables.

If we substitute 562,394, the average annual number *returned* as born alive in Prussia for a period of time (1839, '40, '41) of which the year 1840 was the middle, for 594,851, the approximate number just computed, we shall find

$$\lambda\, p_{0/1} = \bar{1}.9109082 = \lambda\ .81453,$$
$$\lambda\, p_{0/3} = \bar{1}.8544920 = \lambda\ .71531,$$
$$\lambda\, p_{0/5} = \bar{1}.8298000 = \lambda\ .67577;$$

and out of 103,461 born alive 84,272 will survive one year,

74,006 " three years,
69,916 " five years,

and the average future duration of life from birth will appear to have been 35.61 years.

A *general interpolation* of the logarithms of the proportions surviving each anniversary of birth intermediate the specified ages, gives the following.

PRUSSIAN LIFE-TABLE, CALCULATED FROM THE AGES OF THOSE DYING DURING THE THREE YEARS 1839, '40, '41; AND FROM THE AGES OF THE LIVING COMPUTED WITH REFERENCE TO THE MIDDLE OF THE YEAR 1840.

Ages.	Logarithms of the Numbers Born, and Living at each Age. λL_x	Logarithms of the Probability, at each Age, of Living One Year. $\frac{\lambda L_{x+1} - \lambda L_x}{\lambda p_x}$	Differences between Consecutive Logarithms of the Probability of Living. $\frac{\lambda p_x - \lambda p_{x+1}}{-\Delta \lambda p_x}$	Persons Born, and Living at each Age. L_x	Persons Dying during each Year of Age. $\frac{L_x - L_{x+1}}{D_x}$	Average Future Duration (or Expectation) of Life. E_x
0	5.001688	.917080 — 1.	— 51797	100,389	17,448	36.66
1	4.918768	.968877	— 10576	82,941	5,736	
2	4.887645	.979453	— 7597	77,205	3,568	
3	4.867098	.987050	— 3378	73,637	2,163	
4	4.854148	.990428	— 1854	71,474	1,558	
5	4.844576	.992282	— 1678	69,916	1,232	47.06
6	4.836858	.993960	— 1241	68,684	948	
7	4.830818	.995201	— 886	67,736	745	
8	4.826019	.996087	— 601	66,991	601	
9	4.822106	.996688	— 381	66,390	504	
10	4.818794	.997069	— 210	65,886	443	44.81
11	4.815863	.997279	— 84	65,443	409	
12	4.813142	.997363	4	65,034	393	
13	4.810505	.997359	63	64,641	392	
14	4.807864	.997296	99	64,249	399	
15	4.805160	.997197	120	63,850	411	41.17
16	4.802357	.997077	121	63,439	425	
17	4.799434	.996956	123	63,014	440	
18	4.796390	.996833	114	62,574	455	
19	4.793223	.996719	107	62,119	468	
20	4.789942	.996612	101	61,651	479	37.54
21	4.786554	.996511	95	61,172	489	
22	4.783065	.996416	95	60,683	499	
23	4.779481	.996321	100	60,184	508	
24	4.775802	.996221	106	59,676	517	
25	4.772023	.996115	118	59,159	527	34.02
26	4.768138	.995997	121	58,632	538	
27	4.764135	.995876	125	58,094	549	
28	4.760011	.995751	128	57,545	560	
29	4.755762	.995623	133	56,985	571	
30	4.751385	.995490	137	56,414	583	30.55
31	4.746875	.995353	140	55,831	594	
32	4.742228	.995213	144	55,237	606	
33	4.737441	.995069	151	54,631	617	
34	4.732510	.994918	153	54,014	628	
35	4.727428	.994765	158	53,386	640	27.14
36	4.722193	.994607	159	52,746	651	
37	4.716800	.994448	161	52,095	661	
38	4.711248	.994287	165	51,434	673	
39	4.705535	.994122	171	50,761	682	
40	4.699657	.993951	185	50,079	693	23.76
41	4.693608	.993766	204	49,386	703	
42	4.687374	.993562	230	48,683	717	
43	4.680936	.993332	258	47,966	731	
44	4.674268	.993074	291	47,235	747	
45	4.667342	.992783	323	46,488	766	20.40
46	4.660125	.992460	352	45,722	787	
47	4.652585	.992108	391	44,935	809	
48	4.644693	.991717	438	44,126	834	
49	4.636410	.991279	498	43,292	860	
50	4.627689	.990781 — 1.	570	42,432	892	17.11

Ages.	Logarithms: Of the Numbers Born, and Living at each Age. λL_x	Logarithms: Of the Probability, at each Age, of Living One Year. $\frac{\lambda L_{x+1} - \lambda L_x}{\lambda p_x}$	Differences between Consecutive Logarithms of the Probability of Living. $\frac{\lambda p_x - \lambda p_{x+1}}{-\Delta \lambda p_x}$	Persons: Born, and Living at each Age. L_x	Persons: Dying during each Year of Age. $\frac{L_x - L_{x+1}}{D_x}$	Average Future Duration (or Expectation) of Life. E_x
51	4.618470	.990211 — 1.	651	41,540	925	
52	4.608681	.989560	745	40,615	965	
53	4.598241	.988815	851	39,650	1,008	
54	4.587056	.987964	970	38,642	1,057	
55	4.575020	.986994	1101	37,585	1,108	13.98
56	4.562014	.985893	1307	36,477	1,166	
57	4.547907	.984586	1491	35,311	1,231	
58	4.532493	.983095	1657	34,080	1,302	
59	4.515588	.981438	1803	32,778	1,371	
60	4.497026	.979635	1934	31,407	1,439	11.22
61	4.476661	.977701	2042	29,968	1,500	
62	4.454362	.975659	2137	28,468	1,551	
63	4.430021	.973522	2215	26,917	1,592	
64	4.403543	.971307	2275	25,325	1,619	
65	4.374850	.969032	2323	23,706	1,632	9.03
66	4.343882	.966709	2330	22,074	1,629	
67	4.310591	.964379	2337	20,445	1,610	
68	4.274970	.962042	2345	18,835	1,576	
69	4.237012	.959697	2351	17,259	1,530	
70	4.196709	.957346	2360	15,729	1,471	7.36
71	4.154055	.954986	2367	14,258	1,404	
72	4.109041	.952619	2414	12,854	1,328	
73	4.061660	.950205	2828	11,526	1,249	
74	4.011865	.947377	2988	10,277	1,173	
75	3.959242	.944389	3157	9,104	1,094	5.97
76	3.903631	.941232	3338	8,010	1,014	
77	3.844863	.937894	3527	6,996	932	
78	3.782757	.934367	3726	6,064	851	
79	3.717124	.930641	3939	5,213	769	
80	3.647765	.926702	4162	4,444	690	4.80
81	3.574467	.922540	4399	3,754	613	
82	3.497007	.918141	4648	3,141	540	
83	3.415148	.913493	4913	2,601	470	
84	3.328641	.908580	5191	2,131	404	
85	3.237221	.903389	5485	1,727	345	3.82
86	3.140610	.897904	5799	1,382	289	
87	3.038514	.892105	6126	1,093	241	
88	2.930619	.885979	6475	852	196	
89	2.816598	.879504	6842	656	159	
90	2.696102	.872662	7231	497	127	3.02
91	2.568764	.865431	7641	370	98	
92	2.434195	.857790	8076	272	76	
93	2.291985	.849714	8534	196	57	
94	2.141699	.841180	9019	139	43	
95	1.982879	.832161	9530	96	31	
96	1.815040	.822631	10072	65	22	
97	1.637671	.812559	10644	43	15	
98	1.450230	.801915	11248	28	10	
99	1 252145	.790667	11887	18	7	
100	1.042812	.778780	12562	11	4.4	
101	0.821592	.766218	13275	6.6	2.7	
102	0.587810	.752943	14029	3.9	1.7	
103	0.340753	.738914	14826	2.2	1.0	
104	0.079667	.724088 — 1.		1.2	.6	
105	1.803755			.6	.6	

The leading features in the interpolated Life-Table for Prussia are two.

1st. Strict conformity at certain points to values calculated from actual data.

2d. Regularity in the graduation.

It will be observed that the logarithms of the proportions born alive and surviving ages 1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85, as calculated from actual data, are identical with those in the interpolated table. More frequent coincidence would fail, for certain intervals of age, to secure the desired regularity.

From these values we find, by inspection, that the logarithms of the reciprocals of the probabilities of surviving equal consecutive intervals of age diminish from birth, until they attain a minimum between ages 5 and 25 (near age 14), then gradually increase for subsequent intervals.

In effecting the interpolation, we sought to arrive only at results that, coinciding at the ages above specified with those derived from the actual data, should represent the logarithms of the reciprocals of the probabilities of surviving consecutive annual intervals of age as diminishing from birth to a minimum at some point between ages 5 and 25, then gradually increasing for subsequent intervals of age; and that the differences between these logarithms should also advance without manifest irregularity, increasing from, at latest, age 25 to extreme old age.

Two distinct functions of interpolation were employed.

1st. The *exponential.*

For λL_x, write ϕ_x.

$$\phi_x = \phi_a + (\phi_b - \phi_a)\frac{q^{x-a} - 1}{q^{b-a} - 1},$$

in which ϕ_a, ϕ_b, ϕ_c are known values of the function ϕ_x, corresponding to ages a, b, and c. q is to be determined. If the terms be *equidistant*, that is, if $c - b = b - a$,

$$q^{b-a} = \frac{\phi_c - \phi_b}{\phi_b - \phi_a},$$

and

$$\phi_x = \phi_a + \frac{(\phi_b - \phi_a)^2}{(\phi_c - \phi_b) - (\phi_b - \phi_a)} \cdot (q^{x-a} - 1).$$

If the terms be *not* equidistant, the determining of q will involve the solution of quadratic or higher equations.

2d. The *algebraic.*

$$\phi_x = \phi_a \frac{A_x}{A_a} + \phi_b \frac{B_x}{B_b} + \phi_c \frac{C_x}{C_c} + \phi_d \frac{D_x}{D_d} \ldots\ldots + Q\,\Pi_x;$$

in which

$$\Pi_x = x - a \,.\, x - b \,.\, x - c \,.\, x - d \,.\, \ldots\ldots,$$

and

$$A_x = \frac{\Pi_x}{x - a},\ B_x = \frac{\Pi_x}{x - b},\ C_x = \frac{\Pi_x}{x - c},\ D_x = \frac{\Pi_x}{x - d},\ \ldots\ldots;$$

Q may be zero, or an arbitrary constant real and finite, or a real function involving only integral powers of the variable, and which cannot cause the term $(Q\,\Pi_x)$ to become infinite or indeterminate for any value of the variable within the limits assigned for interpolation, or between those corresponding to the extreme given values of the function.

When $x = a$, $\frac{A_x}{A_a}$ { obviously becomes *unity*, and terms independent of this factor *vanish.*

b, $\frac{B_x}{B_b}$ " " "

c, $\frac{C_x}{C_c}$ " " "

d, $\frac{D_x}{D_d}$ " " "

Another convenient function for interpolation when three terms are given, but which was not employed in framing the present table, is the general *parabolic.*

$$\phi_x = \phi_a + (\phi_b - \phi_a)\left(\frac{x - a}{b - a}\right)^q,$$

in which

$$q = \frac{\lambda \dfrac{\phi_c - \phi_a}{\phi_b - \phi_a}}{\lambda \dfrac{c - a}{b - a}}.$$

The exponential involves but *three* known values of the function.

The number of known values that may enter into the interpolation by the algebraic is *unlimited;* but, without care, the resulting series will often be quite eccentric.

Given, logarithms of the proportions born alive, and surviving ages

1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85; required (λL_x) the logarithms of the proportions surviving each intermediate anniversary of birth.

By the exponential formula values between ages

25 and 38	were respectively interpolated from known values of the function for ages	25, 35, and 45.
35 and 48		35, 45, and 55.
45 and 58		45, 55, and 65.
55 and 68		55, 65, and 75.

Values from 73 to age 105, inclusive, were interpolated from known values of the function for ages 65, 75, and 85.

By the above it appears that duplicate values were obtained at ages 36 and 37, 46 and 47, 56 and 57.

The results deduced from these interpolations conform strictly to the conditions imposed, except near the joining points of the several series, where appear irregularities in the first and second orders of differences. These manifest irregularities were then corrected for the several intervals, by adding to the result at each of the several ages the corresponding value of Δ_x, derived from the simple algebraic function

$$\Delta_x = \Delta_g \frac{x-a \,.\, x-b \,.\, x-c \,.\, x-h}{g-a \,.\, g-b \,.\, g-c \,.\, g-h} + \Delta_h \frac{x-a \,.\, x-b \,.\, x-c \,.\, x-g}{h-a \,.\, h-b \,.\, h-c \,.\, h-g}.$$

In applying the correction to ages between 35 and 48, a, b, c, g, and h equalled respectively 35, 45, 55, 36, and 37. Δ_{36} and Δ_{37} were the differences between the duplicate values for ages 36 and 37. The difference was positive when the one of the duplicate values first obtained was the greater.

In correcting between ages 45 and 58, a, b, c, g, and h equal respectively 45, 55, 65, 46, and 47, and Δ_{46} and Δ_{47} were the differences respectively between the λL_{46} and λL_{47} just corrected, and the corresponding results derived by the exponential formula from values for ages 45, 55, and 65.

By a similar process the correction was made for values between ages 55 and 68.

A slight irregularity still existing in the second differences (the first differences from the logarithms of the probability of living) near

the joining of the series about age 36, another correction was made to the values between ages 37 and 45, viz. :

$$\Delta_x = \Delta_{34} \frac{x-35 \,.\, x-36 \,.\, x-37 \,.\, x-45 \,.\, x-46 \,.\, x-47}{34-35 \,.\, 34-36 \,.\, 34-37 \,.\, 34-45 \,.\, 34-46 \,.\, 34-47}.$$

The values for Δ_{34}, being the difference between the first of the duplicate λL_{34} and the corrected second of the duplicates. Δ_x is additive, if the first of the duplicate values for λL_{34} is the greater.

The values between ages 67 and 73, inclusive, were computed from the known values at ages 65, 66, 67, and 73, by assuming the third order of differences constant.

$$\lambda L_{72} = \lambda L_{66} + 8\Delta + 28\Delta_2 + 56\Delta_3.$$

Δ and Δ_2 were derived from the original value for λL_{65}, and from the corrected values for λL_{66} and λL_{67}. Δ_3 was then readily found, and consequently the values required between ages 67 and 73. A modification of the method here indicated might have been applied with advantage to the correction of irregularities near the points of junction in other parts of the table.

From the given values of λL_x for ages 3, 5, 14, 25, 35, together with the values of λL_x for ages 26 and 27, computed as above, the unknown values between ages 5 and 26 were interpolated by the algebraic formula

$$\lambda L_x = \phi_x = \phi_3 \frac{A_x}{A_3} + \phi_5 \frac{B_x}{B_5} + \phi_{14} \frac{C_x}{C_{14}} + \phi_{25} \frac{D_x}{D_{25}} + \phi_{26} \frac{E_x}{E_{26}} + \phi_{27} \frac{F_x}{F_{27}} + \phi_{35} \frac{G_x}{G_{35}}.$$

The forms of the functions A, B, C, &c. have been previously given.

From λL_1, λL_2, and λL_5 values were deduced by the exponential formula for λL_2 (= 4.887645) and λL_4 (= 4.854456).

By the same formula, from λL_3, λL_5, and the computed value for λL_7 was deduced a duplicate value for λL_4 (= 4.853532). From comparison of the duplicate values for λL_4, giving to the former double weight, we obtain 4.854148.

We remark that the desired regularity in the graduation, for the greater part of the table, was attained by making identical three or more consecutive values of adjoining series.

It will be observed that the interpolated results represent mortality

diminishing from birth, until attaining a minimum about age 12, then increasing gradually to age 105, the assumed terminating age of the table. Also, that the values in the column of differences headed $-\Delta\lambda p_x$ gradually increase through the greater part of the entire table, diminishing, however, between ages 17 and 22. A curve, to which the intervals of age and corresponding intensities of mortality are co-ordinates, will be concave downwards through the space where these differences diminish, if elsewhere concave upwards. The attainment of regularity at joining points in the order of differences next higher, was deemed unimportant. For the accuracy with which much of the arithmetical computation has been performed, in the preparation of this and certain other tables following, credit is due to Mr. Howard D. Marshall, of Boston.*

Life-Tables, advancing, by regular gradations, from birth to extreme old age, and conforming strictly at convenient intervals to values derived from original data, are uncommon.

The graduation of the older tables was very imperfect. The Carlisle gives the annual rate of mortality at age 20 greater than at 23; at 31, greater than at 34; at 46 greater than at 51; at 88 greater than at 89; and at 91 the same as at 101. Mr. Milne's excellent table for Sweden and Finland, (1801–5,) though less faulty, is still irregular; so also those of De Parcieux, Kersseboom, Finlaison, and others.

The valuable and elaborate English Life-Tables prepared by Dr. Farr, and published in the Reports of the Registrar-General (England), and also the one prepared by a committee of eminent actuaries to represent a law of mortality according to the combined experience of Insurance Companies, as published by Mr. Jenkin Jones, vary the results derived from actual data, to conform to assumed laws. The graduation of the Actuaries' Table is unexceptionable; that of the tables of Dr. Farr nearly so.

The important tables presented by Mr. E. J. Farren, in his instructive treatise entitled, "Life Contingency Tables, Part I.," begin with age 21, and conform strictly at decennial points to values derived from actual data. The function of interpolation adopted by him was the Calculus of Finite Differences, so far as possible; assuming, however, the intensity of mortality to advance by a constant ratio, when, either from paucity of data or other sufficient cause, the Calculus of

* Mr. Marshall has deceased since this paper was prepared, and in press.

Finite Differences was inapplicable. The results attained are entirely regular.

Many writers on this subject have felt it desirable that some simple generic law be discovered, which, by suitable changes in the constants, will *approximate* the specific laws of human mortality indicated by known tables. Among the more philosophical conceptions is the one of Mr. Gompertz (Philosophical Transactions, 1825), that for the greater part of life man momentarily loses "equal proportions of his remaining power to oppose destruction"; and consequently, that the intensity of mortality increases with advancing age by a constant ratio. Mr. Edmonds would have "the force of mortality at all ages" "expressible by the terms of three geometric series, so connected that the last term of one series is the first of the succeeding series." Dr. Farr recognized the principle in framing his English Tables for 1841; treating "the two series of numbers representing the mortality from 15 to 55, and from 55 to 95, as geometrical progressions. The ratios were derived from a comparison of the increase in the mortality at 15–20, 25–30, 35–40, &c.; and the increase at 20–25, 30–35, 40–45, &c.; and the first terms were derived from these ratios, and the sums of the series which they formed."

Mr. Orchard's method, as described by Mr. Gray in the Assurance Magazine, (London,) for July, 1856, was the adoption of "two consecutive series, having constant second differences," to represent the proportions living from age 20 to 80 and from 80 to 96, the terminating age of his table. He wished "to find a *simple algebraical* relation which should passably well represent some of our best tables." The advantage claimed for a table so constituted "is, that it admits, by the application of simple analytical processes, of the independent formation of any of the values which ordinarily require the aid of a formidable array of the results of previous computation." The same paper gives a *single* algebraical function of the second degree proposed by Mr. Babbage, which is said to represent, nearly, the Swedish Table of Mortality.

Other methods have been proposed by mathematicians of established reputation.*

* A valuable contribution to this department of the science of Vital Statistics was read before the American Association, at its late meeting, by President McCay of South Carolina.

The intensity of mortality at age z (when deaths are uniformly distributed) being the middle term $\left(\frac{-d\,L_z}{L_z}\right)$ of a series of reciprocals of an arithmetical progression, is less by a small proportion than the average value of the terms constituting the series; hence $(m_{a/b})$ the rate of annual mortality for the interval of age $b - a$ is somewhat *less* (in the case of such uniform distribution) than $\left(\int_a^b m_{dz} \cdot dz\right)$ the integral rate of mortality for the interval, or than its equivalent $(-\lambda\, p_{a/b})$, the Napierian logarithm, with the sign changed, of the probability that one living at the earlier age (a) will attain the later age (b).

To convert the Napierian to the common logarithm, we multiply by μ $(= .4342945)$, the modulus of the common system.

PRUSSIA. 1839, '40, '41.

TABLE COMPARING LOGARITHMS OF PROBABILITIES OF SURVIVING, COMPUTED BY DIFFERENT METHODS.

Ages a, b.	Ratio of Deaths to Population. Mortality. m	Common Logarithm, with changed Sign, of the Probability that one living at the Earlier Age in each Interval will attain the Later. Integral. $-\lambda\, p$ each from *three* consecutive Ratios.	Approximate. $-\lambda \frac{1 - m\frac{b-a}{2}}{1 + m\frac{b-a}{2}}$	$-(b-a)\lambda \frac{1-\frac{m}{2}}{1+\frac{m}{2}}$	$-(b-a)\mu \cdot m$
	A	B	C	D	E
0 – 5	.0802238	.157112*	.176598	.174297	.174204
5 – 7	.0152056	.013155	.013208	.013208	.013208
7 – 14	.0077790	.023557	.023655	.023649	.023649
14 – 20	.0062978	.016416	.016413	.016411	.016411
20 – 25	.0089397	.019425	.019416	.019412	.019412
25 – 30	.0096939	.021058	.021054	.021050	.021050
30 – 35	.0108317	.023537	.023527	.023521	.023521
35 – 40	.0131780	.028637	.028626	.028616	.028616
40 – 45	.0144675	.031449	.031430	.031416	.031416
45 – 55	.0210345	.092322	.091691	.091355	.091352
55 – 60	.0357042	.077981	.077738	.077539	.077531
60 – 65	.0557995	.122189	.121962	.121199	.121167
65 – 75	.0909134	.415608	.425992	.395105	.394832
75 – 85	.1515098	.722021	.860283	.659260	.657999
85 and upw'ds	.2661784			1.162896	1.155998

* This value was calculated by a process described in the preceding paper, from population under age 5; from deaths for the intervals of age 0 – 1, 1 – 3, and 3 – 5; and from the rate of annual increase of births estimated from registered births for the six years 1836 – 41.

ENGLAND AND WALES.

TABLE COMPARING LOGARITHMS OF PROBABILITIES OF SURVIVING, COMPUTED BY DIFFERENT METHODS.

Deaths (*Seven Years*) 1838 - 44.

Population computed to Middle of 1841.

Ninth Rep. Reg.-Gen., pp. 176, 177.

Ages a, b.	Ratio of Deaths to Population. MORTALITY. m	Common Logarithm, with changed Sign, of the Probability that one living at the Earlier Age in each Interval will attain the Later. INTEGRAL. $-\lambda p$ Duplicate Values, each from *two* consecutive Ratios.	Mean of the Duplicate Values.	APPROXIMATE. $-\lambda \frac{1-m\frac{b-a}{2}}{1+m\frac{b-a}{2}}$	$-(b-a)\lambda \frac{1-\frac{m}{2}}{1-\frac{m}{2}}$	$-(b-a)\mu . m$
	A	*B*		*C*	*D*	*E*
0 - 1	.1792379	.077265	.073073*	.078052	.078052	.077842
1 - 2	.0654971	.028133 .028379	.028256	.028455	.028455	.028445
2 - 3	.0351076	.015206 .015235	.015220	.015249	.015249	.015247
3 - 4	.0250056	.010850 .010854	.010852	.010860	.010860	.010860
4 - 5	.0184203	.007995 .007998	.007997	.008000	.008000	.008000
5 - 10	.0091272	.019686 .019789	.019738	.019823	.019820	.019819
10 - 15	.0052572	.011397 .011425	.011411	.011417	.011416	.011416
15 - 25	.0081967	.035723 .035643	.035683	.035618	.035598	.035598
25 - 35	.0098929	.043033 .043045	.043039	.042999	.042966	.042964
35 - 45	.0124582	.054239 .054261	.054250	.054176	.054105	.054105
45 - 55	.0165886	.072341 .072636	.072489	.072209	.072044	.072043
55 - 65	.0295429	.130216 .130452	.130334	.129249	.128313	.128303
65 - 75	.0622301	.283777 .278012	.280895	.279528	.270349	.270262
75 - 85	.1374474	.718169 .649789	.683979	.731961	.597869	.596926
85 - 95	.2842092	1.127822			1.242716	1.234305
95 - +	.4146003				1.827064	1.800586

* This value was derived from the registered births for the eleven years 1839 - 49, and from the registered deaths under one year of age for the ten years 1840 - 49.

In each of the preceding Tables, column *A* gives rates of annual MORTALITY for the several specified intervals of age, or ratios of the average numbers annually dying in the community within the specified intervals to the numbers living within the same intervals, estimated with reference to the middle of the year or period in which the deaths occurred.

Column *B* with changed signs gives the common logarithms of the probabilities of surviving the specified intervals, each computed from THREE consecutive ratios in the column of mortality by a process described in the preceding paper. These values, which we designate *integral* values, may be assumed without appreciable error to represent truly the results demanded by actual data, and with them may be compared *approximate* values obtained by simpler processes.

The *approximate* values in the columns *C*, *D*, and *E* were each derived from SINGLE ratios in *A*.

The values in *C* were each obtained by first multiplying (m) the annual rate of mortality by $\left(\frac{b-a}{2}\right)$ half the number of years in the interval of age; then finding the logarithm, with changed sign, of the quotient of unity *less* this product divided by unity *plus* this product.

The values in *D* were each found by multiplying the number of years in the respective interval by the logarithm, with changed sign, of the quotient of unity *less* half the rate of mortality divided by unity *plus* half the rate.

The values in *E* were each found by multiplying the mortality by .4342945 (μ), the modulus of the common system of logarithms, and by ($b-a$) the number of years in the respective interval of age.

Whenever the decrements in the Life-Table resulting from the original data are constant, the corresponding result in *C* represents the logarithm, with changed sign, of the probability of surviving the *entire interval;* that in *D* represents the product of ($b-a$) the number of years in the interval, multiplied by the logarithm, with changed sign, of the probability of surviving the *middle year* of the interval; and that in *E* the product of $\left(\frac{b-a}{dz}\right)$ the number of equal moments in the interval, multiplied by the logarithm, with changed sign, of the probability of surviving a moment of time at the middle of the interval. Whenever the decrements in the Life-Table are *increasing*, the above

results are each *less* than the respective logarithm; and when *decreasing*, *greater*.

The results in E should in all cases be somewhat less than those in D, although generally the approximation is so close that values in E may without appreciable error be substituted for those in C.

The results in D are likewise less than corresponding ones in C.

The results in C are *less* than the integral values in B, whenever the decrements between the proportions surviving at equidistant ages in the Life-Table, derived from actual data, form a series increasing with the age; they are *equal* to them, when the series is uniform, and *greater* than truth when the series diminishes. By reference to the Prussian Table interpolated for annual intervals, we observe that the decrements diminish from birth to age 13; increase thence to age 65; and again diminish to the age terminating the Table.

The process for deducing values in D is identical with that adopted by Dr. Farr,* in briefly calculating approximate Life-Tables. After determining from values so obtained the proportions of the living at certain ages, he assumed that the proportions within the several intervals were series in arithmetical progression.† It is not unusual, in framing Life-Tables from population and mortality statistics, to let $\frac{1-\frac{1}{2}m}{1+\frac{1}{2}m}$ equal the probability of surviving the middle year of a given interval, then, assuming some law of relation, to determine values for intermediate ages. Results so deduced will commonly represent the probability of living for a large part of life somewhat greater than truth demands.

C. Process for deducing accurate Average Duration of Life, Present Value of Life-Annuities, and other useful Tables involving Life-Contingencies, from Returns of Population and Deaths, without the Intervention of a General Interpolation.

The logarithms of the proportions surviving at certain ages (λL_x) are obtained, by successively adding to the logarithm of a number as-

* To this distinguished writer the science of vital statistics is largely indebted for valuable, extensive, and varied contributions.

† Fifth Report Reg.-Gen. Eng., p. 362.

sumed living at birth, or other specified age, the logarithms of the probabilities of surviving subsequent intervals. Processes for accurately and for approximately determining the logarithms of the probabilities of surviving have been indicated in the previous papers.

Average future duration (or expectation) of life (E_x) expressed in years for any age (x) may be obtained by multiplying by the differential of the age (dx) the integral of the proportions surviving within the limits of the given age and of the greatest tabular age $\left(\int_x^{105} L_x\right)$, and dividing the product by the proportions living at the given age.

That is,

$$E_x = \frac{dx \int_x^{105} L_x}{L_x},$$

in which 105 is assumed the greatest tabular age.

A close approximation to this value may be found by dividing $(\sum_x^{106} L_x = L_x + L_{x+1} + \ldots . L_{105})$ the sum of the proportions living at the given age and at each subsequent anniversary by (L_x) the proportions living at the given age, and from the quotient deducting the half of unity; that is,

$$E_x = \frac{\sum_x^{106} L_x}{L_x} - \tfrac{1}{2}, \text{ nearly.}$$

The latter is the more common process.

The formula expressing the value of a life-annuity, or the present value of one dollar payable at the end of each year during the remainder of the life of the annuitant after attaining a given age, is

$$\frac{L_{x+1} v + L_{x+2} v^2 + \ldots . L_{105} v^{105-x}}{L_x};$$

in which v is the present value of one dollar due one year hence at a given rate of interest.

This expression may readily be converted into the well-known symmetrical form

$$\frac{L_{x+1} v^{x+1} + L_{x+2} v^{x+2} + \ldots . L_{105} v^{105}}{L_x v^x},$$

which equals

$$\frac{L_x v^x + L_{x+1} v^{x+1} + L_{x+2} v^{x+2} + \ldots . L_{105} v^{105}}{L_x v^x} - 1,$$

$$= \frac{\sum_x^{106} L_x v^x}{L_x v^x} - 1.$$

Given (L_0, L_1, L_3, &c.) the proportions born, and surviving ages 1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85, according to the law of mortality prevailing in Prussia; required corresponding average future duration of life, life-annuities, and premiums annual and single.

In order to determine values for $\int_x^{105} L_x$ and $\sum_x^{106} L_x v^x$, some law of relation must be supposed to exist between the known values of each of the functions L_x and $L_x v^x$; and this law obviously should represent numbers diminishing with advancing age.

The law may either be expressed by a single formula (as, for instance, the algebraic of the eleventh order), or by a series of distinct formulæ. In consequence of the very great arithmetical labor involved in its practical application, it will not often be thought desirable to adopt a single formula.

When the known values are *equidistant*, n being the number of years in each interval, let

$$S_x = L_x + L_{x+n} + L_{x+2n} + \ldots,$$

and

$$S'_x = L_x v^x + L_{x+n} v^{x+n} + L_{x+2n} v^{x+2n} + \ldots;$$

then will

$$\int_x^{105+} L_x = \int_x^{x+n} S_x,$$

and

$$\sum_x^{106} L_x v^x = \sum_x^{x+n} S'_x.$$

Formulæ which express laws of relation supposed to exist between *four* given values we style *four-point formulæ;* and so for any other number of given values.

The solution of the *four-point algebraic equation*

$$X = \alpha + \beta x + \gamma x^2 + \delta x^3,$$

in which α, β, γ, δ are unknown, and independent of the variable (x), may assume several forms; one of the more convenient of which for our present purpose is

$$X = B \frac{x-c}{b-c} + C \frac{x-b}{c-b} + x-b \,.\, x-c \left\{ \begin{array}{r} \theta_A^2 \dfrac{x-d}{a-d} \\ + \theta_B^2 \dfrac{x-a}{d-a} \end{array} \right\},$$

in which

$$\theta_A^2 = \left\{\frac{C-B}{c-b} - \frac{B-A}{b-a}\right\}\frac{1}{c-a},$$

$$\theta_B^2 = \left\{\frac{D-C}{d-c} - \frac{C-B}{c-b}\right\}\frac{1}{d-b},$$

and A, a, B, b, C, c, D, d, are known corresponding values of the co-ordinates X, x.

Then will

$$dx\int_b^c X = \frac{c-b}{2}\left\{C + B - \frac{\overline{c-b}^2}{3}\left\{\begin{matrix}\theta_A^2\,\dfrac{d-\frac{1}{2}\overline{b+c}}{d-a}\\ +\theta_B^2\,\dfrac{a-\frac{1}{2}\overline{b+c}}{a-d}\end{matrix}\right\}\right\}$$

$$= \frac{c-b}{2}\{C + B + H\};$$

in which H is substituted for

$$-\frac{\overline{c-b}^2}{3}\left\{\begin{matrix}\theta_A^2\,\dfrac{d-\frac{1}{2}\overline{b-c}}{d-a}\\ +\theta_B^2\,\dfrac{a-\frac{1}{2}\overline{b-c}}{a-d}\end{matrix}\right\}.$$

Also,

$$\frac{C-B}{2} + \Sigma_b^c X = \frac{c-b}{2}\left\{C + B + \left(1 - \frac{1}{\overline{c-b}^2}\right)H\right\}.$$

If the terms be equidistant, that is, if

$$d - c = c - b = b - a,$$

H becomes

$$\frac{C + B - \overline{D+A}}{12}.$$

Then

$$dx\int_b^c X = \frac{c-b}{2}\left\{C + B + \frac{C + B - \overline{D+A}}{12}\right\},$$

and

$$\frac{C-B}{2} + \Sigma_b^c X = \frac{c-b}{2}\left\{C + B + \frac{C + B - \overline{D+A}}{12}\left(1 - \frac{1}{\overline{c-b}^2}\right)\right\}.$$

The *three-point exponential* formula

$$X = \alpha + \beta\gamma^x,$$

α, β, and γ being unknown, and independent of the variable x, may take the form

$$X = A + (B - A)\,\frac{q^{x-a} - 1}{q^{b-a} - 1};$$

in which

$$\frac{q^{c-a} - 1}{q^{b-a} - 1} = \frac{C - A}{B - A},$$

whence may be determined the value of q.

$$\left.\begin{array}{r} d\,x \int_a^b X = \frac{1}{Q} \\ \frac{B-A}{2} + \Sigma_a^b X = \frac{1}{2}\frac{q+1}{q-1} \end{array}\right\} \overline{B-A} + \overline{b-a}\left\{A - \frac{B-A}{q^{b-a}-1}\right\}$$

$$\left.\begin{array}{r} d\,x \int_b^c X = \frac{1}{Q} \\ \frac{C-B}{2} + \Sigma_b^c X = \frac{1}{2}\frac{q+1}{q-1} \end{array}\right\} \overline{C-B} + \overline{c-b}\left\{A - \frac{B-A}{q^{b-a}-1}\right\}$$

Q is the Napierian logarithm of q.

When the terms are equidistant, i. e. $c - b = b - a$,

$$q = \left(\frac{C-B}{B-A}\right)^{\frac{1}{b-a}};$$

$$\frac{1}{Q} = \frac{\overline{b-a} \cdot \mu}{\lambda \dfrac{C-B}{B-A}};$$

and

$$\frac{B-A}{q^{b-a}-1} = \frac{\overline{B-A}^2}{\overline{C-B-B-A}}.$$

μ is (.4342945) the modulus of the common system of logarithms.

When the terms are not equidistant, the application of the exponential function involves the resolution of equations of higher than the first degree.

The *three-point parabolic* formula

$$X = \alpha + \beta\,(x - a)^{\gamma}$$

may become

$$X = A + (B - A)\left(\frac{x-a}{b-a}\right)^{q};$$

in which

$$q + 1 = \frac{\lambda \dfrac{\overline{C-A} \cdot \overline{c-a}}{\overline{B-A} \cdot \overline{b-a}}}{\lambda \dfrac{c-a}{b-a}}.$$

Then will

$$d\,x\int_a^b X = \overline{b-a}\,A + \frac{\overline{b-a}\,.\,\overline{B-A}}{q+1}$$

and

$$d\,x\int_b^c X = \overline{c-b}\,A + \frac{\overline{c-a}\,.\,\overline{C-A}}{q+1} - \frac{\overline{b-a}\,.\,\overline{B-A}}{q+1}.$$

The *finite* integral of $(x-a)^q$ advances in the form of *a series*, no application of which has been made in the illustrations which follow.

Of the functions above enumerated, the algebraic will commonly prove the most simple in practice, but will not in all cases satisfy the conditions required. When assumed to express the law of relation between certain known values of the function L_x or $L_x v^x$, a portion of the resulting series of numbers between the known values may increase with advancing age, rather than diminish.

The values between B and C, derived from the algebraic formula assigning a law of relation between the *four* known values A, B, C, and D, *lie between* corresponding duplicate values derived from two algebraic formulæ, one a function of the *three* known values A, B, and C, and the other of the *three* values B, C, and D. When the relations of the known values to each other are such that the series resulting from each of the latter formulæ diminish continuously with advancing age from A to C and from B to D respectively, then that portion between B and C of the single algebraic series connecting the four values A, B, C, and D must diminish continuously.

The series of values resulting from the algebraic formula assigning a law of relation between the *three* known values A, B, and C will continuously diminish from A to C *only* when $\frac{A-B}{\overline{b-a}^2}$ and $\frac{B-C}{\overline{c-b}^2}$ are each positive and *greater* than $\frac{A-C}{\overline{c-a}^2}$; or, if the three terms be equidistant, *only* when $\left(\frac{B-A}{C-B}\right)$ the value of the ratio of the first differences is between $\frac{1}{3}$ and 3, and the differences themselves negative. Similar relations obviously obtain when the three known values are B, C, and D.

Applying this test to the Prussian Life-Table, we first find that the algebraic function assigning a law of relation between the *three* known values does not completely satisfy the conditions for the proportions surviving ages 0, 1, 3; 3, 5, 14; 75, 85, 95; and 85, 95, 105; that

is, for the extremes of the table, the values there rapidly diminishing; and also for ages 3, 5, and 14, where there is a great disparity in the length of the intervals of age. It will hereafter appear that eccentricities at the older ages may be disregarded in constructing tables of future duration of life, and of life-annuities, without materially affecting the correctness of the results for earlier ages.

TABLE I.

AVERAGE FUTURE DURATION OF LIFE IN PRUSSIA.

Algebraic Integration.

Ages.	Proportions Born, and Living at Specified Ages in Prussia, calculated by the Integral Method, from *three* Consecutive Ratios of Deaths to Population.			Sum of (L_x) the Proportions Living at the given Age and at all subsequent Ages specified.	Aggregate Number of Future Years that (L_x) the Proportions surviving Specified Ages will live.	Average Future Duration of Life.
	L_x	Ages.	L_x	S_x	$dx\int_x^{105} L_x$	E_x
5	69,916	5	69,916	364,916		
14	64,249	15	63,748	295,000	2,626,778	41.21
25	59,159	25	59,159	231,252	2,012,408	34.02
35	53,386	35	53,386	172,093	1,448,721	27.14
45	46,488	45	46,488	118,707	948,047	20.39
55	37,585	55	37,585	72,219	524,773	13.96
65	23,706	65	23,706	34,634	215,941	9.11
75	9,104.2	75	9,104.2	10,927.6	54,597	6.00
85	1,726.7	85	1,726.7	1,823.4	5,847	3.39
		95	96.1	96.7	— 232	
		105	.64	.64		

$L_x + L_{x+10} + L_{x+20} + \ldots + \frac{10}{2}\left\{ + \frac{S_x + S_{x+10}}{S_x + S_{x+10} - S_{x-10} - S_{x-20}} \right\} \frac{}{12}$

$\frac{dx\int_x^{105} L_x}{L_x}$

In the preceding table the *first* of the columns headed L_x gives the proportions surviving certain ages according to the law of mortality prevailing in Prussia; the probability of surviving each of the several intervals being calculated from three consecutive ratios of deaths to populations. In the *second* of the columns headed L_x the values for ages 95 and 105 were computed from the logarithms of the proportions surviving ages 65, 75, and 85, by the exponential formula which expresses the value of the required logarithms in terms of the age, and of the three given logarithms. The number surviving age 15 (63,748) was obtained by assuming an algebraic law of relation for the proportions surviving the *four* ages 5, 14, 25, and 35.

The next column (S_x) gives the sum of the proportions surviving the given age and all subsequent specified ages.

The values in column headed $d\,x \int_x^{105} L_x$ give the aggregate number of future years of life that the proportions surviving given ages will enjoy, according to the prevailing law of mortality, and were each computed from four equidistant values in the preceding column (S_x), by means of the formula

$$d\,x \int_x^{105} L_x = \frac{n}{2}\left\{S_x + S_{x+n} + \frac{S_x + S_{x+n} - S_{x-n} - S_{x+2n}}{12}\right\}.$$

The values thus obtained, divided by the corresponding proportions living, give the average future duration of life.

We have already called attention to the unsatisfactory nature of the values resulting from the use of the algebraic formula when the given numbers rapidly diminish, as in the Life-Table after about age 75.

Table II. will compare corresponding results obtained by different formulæ and processes.

In the third column of Table II. the integrations were effected by the exponential formula when the three given values involved in the equation were equidistant; when not equidistant, the parabolic formula was adopted.

The parabolic and the exponential formulæ each afford results that constantly diminish with advancing age.

The process of integration by the algebraic formula involving four known values is the simplest, and between ages 15 to 75 is entirely satisfactory; from 5 to 15, and from 75 upwards, the values afforded are not so reliable; and from 95 to 105, duration of life is represented as *negative*.

In Table IV. we observe that the first three columns of average future duration of life present results, for the larger part of life, *almost identical*.

Values by the algebraic formula slightly exceed those of the following column, calculated by a combination of parabolic, exponential, and algebraic formulæ. The excess at specified ages from 15 to 55 inclusive is only the one-hundredth part (.01) of a year, or *about four days*.

TABLE II.

COMPARISON OF TEMPORARY AGGREGATE FUTURE DURATION OF LIFE, CALCULATED BY DIFFERENT METHODS, FROM THE PROPORTIONS SURVIVING ACCORDING TO THE PRUSSIAN LIFE-TABLE.

Ages.	Proportions Born alive, and Surviving certain Ages.	The Aggregate Number of Years of Life which the Proportions Surviving at the Commencement of certain Intervals of Age will enjoy during each Interval.				
x	L_x	$dx\int_x^{x+n} L_x$			$\frac{L_{x+n}-L_x}{2}+\Sigma_x^{x+n} L_x$	$\frac{L_{x+n}+L_x}{2}$
		Parabolic and Exponential		Algebraic Formula.	By Annual Interpolation.	Equidifferent Method.
		Duplicates.	Mean.			
0	100,389	87,827*			91,665	91,665
1	82,941	155,560*			155,494	156,578
		155,176				
3	73,637	142,992		142,792	143,251	143,553
		142,359*				
5	69,916	664,403*	665,602	656,124	661,937	668,320
		666,802				
15	63,748	613,405	614,407	614,370	616,016	614,535
		615,410				
25	59,159	563,826	563,653	563,687	563,655	562,725
		563,581				
35	53,386	500,393	500,614	500,674	500,322	499,370
		500,836				
45	46,488	422,257	422,952	423,274	422,990	420,365
		423,648				
55	37,585	311,573	309,273	308,830	311,376	306,455
		306,973				
65	23,706	164,599	160,203	161,341	159,662	164,050
		155,807				
75	9,104	49,992	47,601	48,750	47,769	54,155
		45,211				
85	1,727	7,137	6,412	6,081	6,368	9,115
		5,688				
95	96	285	247	— 194	228	485
		209				
105	1					
115	0					

A comparison of the results in the third column of Table IV. with those arrived at by a general interpolation and direct summation of the proportions surviving each anniversary of birth, exhibits a differ-

* These four values were calculated by the parabolic formula; the other values in the column by the exponential.

ence at specified ages from birth to age 85 inclusive, that in but one case (at age 65) exceeds three one-hundredth parts (.03) of one year, or about *eleven days*.

The former results are deemed in every respect as satisfactory as the latter.

We observe that results by the equidifferent method compared with approved results, from birth to age 45 inclusive, are usually about one tenth of a year in excess; and that for ages above 45 the excess is much greater.

TABLE III.

Future Duration of Life in Prussia.

The Temporary Future Duration of Life for the Proportions Surviving, was computed by the Parabolic Formula from Birth to Age 1; *Exponential, from* 1 *to* 3 *and* 3 *to* 5; *Mean of Parabolic and Exponential, from* 5 *to* 15; *Algebraic, from* 15 *to* 75; *and Mean of Exponential Duplicates, from* 75 *to* 105.

Ages.	Temporary Future Duration of Life.	Future Duration of Life.	Average Future Duration of Life.
x	$dx\int_x^{x+n} L_x$	$dx\int_x^{105} L_x$	$\frac{dx\int_x^{105} L_x}{L_x} = E_x$
0	87,827	3,678,033	36.64
1	155,176	3,590,206	43.29
3	142,992	3,435,030	46.66
5	665,602	3,292,038	47.09
15	614,370	2,626,436	41.20
25	563,687	2,012,066	34.01
35	500,674	1,448,379	27.13
45	423,274	947,705	20.39
55	308,830	524,431	13.95
65	161,341	215,601	9.09
75	47,601	54,260	5.96
85	6,412	6,659	3.85
95	247	247	2.57

TABLE IV.

COMPARISON OF AVERAGE FUTURE DURATION OF LIFE.

Computed, by different Processes, from the Prussian Life-Table.

Ages.	By the Algebraic Formula.	Parabolic, 0 - 1; Exponential, 1 - 3 and 3 - 5; Mean of Parabolic and Exponential, 5 - 15; Algebraic, 15 - 75; Mean of Exponential Duplicates, 75 - 105.	By Annual Interpolation.	Assuming L_x within each Interval to advance by an *Equidifferent Progression.*
0		36.64	36.66	36.77
1		43.29	43.27	43.40
3		46.66	46.63	46.76
5		47.09	47.06	47.19
15	41.21	41.20	41.17	41.28
25	34.02	34.01	34.02	34.09
35	27.14	27.13	27.14	27.24
45	20.39	20 39	20.40	20.53
55	13.96	13.95	13.98	14.21
65	9.11	9.09	9.03	9.61
75	6.00	5.96	5.97	7.00
85	3.39	3.85	3.82	5.55
95		2.57	2.37	5.05

TABLE V.

VALUE, AT CERTAIN AGES, OF ONE DOLLAR TO BE PAID AT THE END OF EACH YEAR DURING THE REMAINDER OF LIFE, ACCORDING TO THE PRUSSIAN LIFE-TABLE, WITH PROCESS FOR DETERMINING.

Interest of Money, Four per Cent. Algebraic Finite Integration.

Ages.	$L_x\left(\frac{1}{1.04}\right)^x$	$L'_x + L'_{x+10} + L'_{x+20} + \ldots.$	$\frac{10}{2}\left\{S'_x + S'_{x+10} + \frac{99}{100}H\right\}$	$\frac{\Sigma_x^{106} L'_x}{L'_x} - 1$
x	L'_x	S'_x	$-\frac{L'_x}{2} + \Sigma_x^{106} L'_x$	Life-Annuity, 4 per Cent.
5	57,466	143,287		
15	35,397	85,821	666,675	18.33
25	22,192	50,424	384,260	16.82
35	13,529	28,232	208,804	14.93
45	7,959	14,703	103,448	12.50
55	4,347	6,744	43,186	9.44
65	1,852	2,397	13,115	6.58
75	481	545	2,306	4.29
85	61.6	63.9	133.6	1.67
95	2.3	2.3	— 13 8	
105	.01	.01		

$$H = S'_x + S'_{x+10} - S'_{x-10} - S'_{x-20}.$$

In Table V. we observe that the ratios of the first differences of the values $\left(L_x \left(\frac{1}{1.04}\right)^x\right)$ in the second column, for ages 65 and over, are not within the required limits, $\frac{1}{3}$ and 3, and, consequently, that the values of the annuity resulting from integration by the algebraic formulæ are to an extent unsatisfactory.

Had the integration of S'_x for the older ages been effected by the exponential formula, the following would have resulted.

Ages.	$-\frac{L'_x}{2} + \Sigma_x^{x+n} S'_x$		$\frac{\Sigma_x^{x+n} S'_x}{L'_x} - 1$
	Duplicates.	Mean.	
55	{ 43,539.1 / 42,671.2 }	43,105	9.42
65	{ 13,417.5 / 12,711.6 }	13,065	6.55
75	{ 2,525.4 / 2,281.3 }	2,403	4.50
85	{ 233.3 / 188.2 }	210.8	2.92

In Table VI. the values in the third column corresponding to intervals between ages 65 and 95 are arithmetical means of duplicate values resulting from finite integration of L'_x by the exponential formula. The value opposite age 95 is a *single* value similarly obtained.

Duplicate Values and Mean.

Ages.	Duplicates.	Mean.
65	{ 10,990.8 / 10,356.0 }	10,673
75	{ 2,312.6 / 2,076.1 }	2,194
85	{ 229.4 / 183.0 }	206.2
	Single Value.	
95	6.3	6.3

In the same column (the third) the value of the summation from 5 to 15 (455,694) is the arithmetical mean of a result (456,371) derived by integration from the parabolic formula involving values in the preceding column for ages 3, 5, and 15, and of another (455,017) obtained by finite integration from the exponential formula involving values for ages 5, 15, and 25.

The remaining values in that column were obtained by the finite integration of a series of distinct algebraic formulæ, each involving four given values of $L_x \left(\frac{1}{1.04}\right)^x$.

When the terms in the second column (L'_x) are equidistant, and the intervals *unity*, $1 - \left(\frac{1}{c - b}\right)^2$ in the expression for the finite integral of the algebraic formula becomes *zero*, and the corresponding values in column third become $\frac{L'_x + L'_{x+1}}{2}$.

In the second column ($L_2 v^2$ and $L_4 v^4$) values for ages 2 and 4 were interpolated by means of the exponential formula involving values for ages 1, 3, and 5.

The value of the life-annuity (a_x) at each of the specified ages was obtained by dividing the corresponding value in the fourth column by that in the second, and from the quotient deducting five tenths of unity.

We observe that annuities from age 15 to 45 inclusive, according to Table V., and for subsequent specified ages according to the modification of that table by the exponential formula, are essentially identical with values in Table VI. at corresponding ages.

Our L'_x (constructed according to Barrett's method) corresponds to the D_x of Mr. Griffith Davies and later writers. Our $\sum_x^{106} L'_x$ (or $\sum_x^{x+n} S'_x$) is the N_x employed by Dr. Farr and Mr. Gray, and the N_{x-1} of Mr. Davies, adopted by Mr. David Jones, Mr. Jenkin Jones, Professor De Morgan, and others.

Unaugmented annual and single premiums to insure $ 100, payable at the end of the year of decease, may be computed by the formulæ commonly employed, and heading the respective columns, or be taken directly from Mr. Orchard's very useful tables of "Assurance Premiums."

TABLE VI.

LIFE-ANNUITY, WITH TABLES PREPARATORY; ALSO TABLES OF UNAUGMENTED ANNUAL AND SINGLE PREMIUMS TO INSURE $100, PAYABLE AT THE END OF THE YEAR IN WHICH LIFE SHALL TERMINATE.

Interest of Money, Four per Cent per Annum. Integration by different Formulæ.

Ages.	$L_x\left(\frac{1}{1.04}\right)^x$	$\frac{L'_{x+n}-L'_x}{2}+\sum_x^{x+n}L'_x$	$\frac{L'_x}{2}+\sum_x^{\infty}L'_x$	Life Annuities, 4 per Cent.	Premiums Unaugmented.	
					Annual.	Single.
				$\frac{\sum_x^{105}L'_x}{L'_x}-1$	$100\left(\frac{1}{1+a_x}-\frac{.04}{1.04}\right)$	$100\left(1-\frac{.04}{1.04}\cdot\frac{1}{1+a_x}\right)$
x	L'_x			a_x		
0	100,389	90,070	1,478,812	14.23	2.72	41.42
1	79,751	75,565	1,388,743	16.91	1.74	31.12
2	71,380	68,422	1,313,178	17.90	1.45	27.31
3	65,463	63,236	1,244,746	18.51	1.28	24.96.
4	61,010	59,238	1,181,520	18.87	1.19	23.58
5	57,466	455,694	1,122,282	19.03	1.15	22.96
15	35,397	282,414	666,588	18.33	1.33	25.65
25	22,192	175,456	384,174	16.82	1.77	31.46
35	13,529	105,356	208,718	14.93	2.43	38.73
45	7,959	60,261	103,362	12.49	3.57	48.12
55	4,347	30,021	43,101	9.42	5.75	59.92
65	1,852	10,673	13,080	6.56	9.38	70.92
75	481	2,194	2,407	4.50	14.34	78.85
85	61.6	206.2	212.5	2.95	21.47	84.81
95	2.3	6.3	6.3			
105	.01					

Methods for determining from the above data the values of other single life benefits, whether uniform, increasing, or decreasing, either for the entire period of life or for limited portions, may readily be devised.

So also methods analogous to those employed in framing the preceding tables may, with advantage, be adopted in constructing tables that shall afford facilities for the ready solution of questions involving *two or more* life contingencies.

We now wish rules for determining, by brief processes, values intermediate between those already obtained.

Either of the formulæ already given may be resorted to; of which the following is the simplest.

$$X = A\frac{x-b\,.\,x-c}{a-b\,.\,a-c} + B\frac{x-a\,.\,x-c}{b-a\,.\,b-c} + C\frac{x-a\,.\,x-b}{c-a\,.\,c-b};$$

A, a, B, b, and C, c being known corresponding values of the co-ordinates X and x.

The algebraic formula involving *four* given values will commonly afford results of a nature entirely satisfactory within the usual limits of inquiry.

Given, A, a, B, b, C, c, and D, d, corresponding known values of X, x; required values intermediate between B and C. If the given terms be equidistant, and

$$n = d - c = c - b = b - a,$$

the algebraic formula will give the following: —

TABLE VII.

SPECIAL FORMULÆ FOR INTERPOLATION, INVOLVING FOUR KNOWN EQUIDISTANT VALUES OF THE FUNCTION.

Algebraic.

Ages.	X
$b + \frac{1}{10}n$	$\frac{1}{10}(9B + C) + \frac{3}{2000}(3.\overline{9B + C} - 19A - 11D)$
$+\frac{2}{10}n$	$\frac{1}{10}(8B + 2C) + \frac{8}{1000}(8B + 2C - 6A - 4D)$
$+\frac{3}{10}n$	$\frac{1}{10}(7B + 3C) + \frac{7}{2000}(3.\overline{7B + 3C} - 17A - 13D)$
$+\frac{4}{10}n$	$\frac{1}{10}(6B + 4C) + \frac{4}{1000}(3.\overline{6B + 4C} - 16A - 14D)$
$+\frac{5}{10}n$	$\frac{1}{2}(B + C) + \frac{1}{16}(B + C - A - D)$
$+\frac{6}{10}n$	$\frac{1}{10}(4B + 6C) + \frac{4}{1000}(3.\overline{4B + 6C} - 14A - 16D)$
$+\frac{7}{10}n$	$\frac{1}{10}(3B + 7C) + \frac{7}{2000}(3.\overline{3B + 7C} - 13A - 17D)$
$+\frac{8}{10}n$	$\frac{1}{10}(2B + 8C) + \frac{8}{1000}(2B + 8C - 4A - 6D)$
$b + \frac{9}{10}n$	$\frac{1}{10}(B + 9C) + \frac{3}{2000}(3.\overline{B + 9C} - 11A - 19D)$

EXAMPLE. — Given, unaugmented annual premiums, from Table VI., corresponding to ages 15, 25, 35, and 45; required the premium for age 28.

The difference between ages 25 and 28 is $\frac{3}{10}$ of (n) the interval of age from 25 to 35; that is 28 is $b + \frac{3}{10}n$.

Then

$$X_{28} = \tfrac{1}{10}(7B + 3C) + \tfrac{7}{2000}(3 \cdot \overline{7B + 3C} - 17A - 13D),$$

in which A, B, C, and D equal respectively 1.33, 1.77, 2.43, and 3.57.

$$\begin{aligned} \tfrac{1}{10}(7B + 3C) &= 1.968 \\ 3(7B + 3C) &= 59.04 \\ 17A + 13B &= 69.02; \\ \therefore \quad X_{28} &= 1.93. \end{aligned}$$

Required a value corresponding to age 40, from data in the column headed $-\frac{L'_x}{2} + \sum_x^{106} L'_x$. The formula is

$$X_{40} = \tfrac{1}{2}(B + C) + \tfrac{1}{16}(B + C - A - D),$$

and the given values are for ages 25, 35, 45, and 55.

$$\begin{aligned} B + C &= 312{,}080, \\ A + D &= 427{,}275; \\ \therefore \quad X_{40} &= 148{,}840. \end{aligned}$$

Table VII. may take the symmetrical form of

TABLE VIII.

SPECIAL FORMULÆ FOR INTERPOLATION, INVOLVING FOUR KNOWN EQUIDISTANT VALUES OF THE FUNCTION.

Algebraic.

Ages. x	X	
$b + \frac{1}{10}n$	$\frac{1}{10}(9B + C)$	$9 \times 1\,(3 \cdot \overline{9B + C} - 19A - 11D)$
$\frac{2}{10}n$	$\frac{1}{10}(8B + 2C)$	$8 \times 2\,(3 \cdot \overline{8B + 2C} - 18A - 12D)$
$\frac{3}{10}n$	$\frac{1}{10}(7B + 3C)$	$7 \times 3\,(3 \cdot \overline{7B + 3C} - 17A - 13D)$
$\frac{4}{10}n$	$\frac{1}{10}(6B + 4C)$	$6 \times 4\,(3 \cdot \overline{6B + 4C} - 16A - 14D)$
$\frac{5}{10}n$	$\frac{1}{10}(5B + 5C) + \frac{1}{8000}$	$5 \times 5\,(3 \cdot \overline{5B + 5C} - 15A - 15D)$
$\frac{6}{10}n$	$\frac{1}{10}(4B + 6C)$	$4 \times 6\,(3 \cdot \overline{4B + 6C} - 14A - 16D)$
$\frac{7}{10}n$	$\frac{1}{10}(3B + 7C)$	$3 \times 7\,(3 \cdot \overline{3B + 7C} - 13A - 17D)$
$\frac{8}{10}n$	$\frac{1}{10}(2B + 8C)$	$2 \times 8\,(3 \cdot \overline{2B + 8C} - 12A - 18D)$
$b + \frac{9}{10}n$	$\frac{1}{10}(B + 9C)$	$1 \times 9\,(3 \cdot \overline{B + 9C} - 11A - 19D)$

And generally, when the four terms A, B, C, and D are equidistant,

$$X = \frac{1}{c-b}(\overline{c-x}\,B + \overline{x-b}\,C) + \frac{1}{6(c-b)^3} \times$$

$$\{\overline{c-x}\,.\,\overline{x-b}\,[3\,.\,(c-\overline{x}\,B + \overline{x-b}\,C) - \overline{d-x}\,A - \overline{x-a}\,D]\}.$$

The writer is not aware that any previous attempt has been made to pass by direct and *summary processes* from the immediate results of actual observations to solutions of monetary and other practical questions involving life contingencies, as *accurate* and *reliable* as those obtained by the intervention of a formidable interpolation. In view of the large and rapidly accumulating mass of population and mortality statistics, such processes seem to be demanded.

The *approximate* methods heretofore published have already been adverted to; allusion has also been made to certain formulæ adopted in the construction of *theoretical* Life-Tables, which afford facilities for the independent formation of required monetary and other values.

NOTE.—The average future duration of life for ages 15, 25, 35, 45, and 55, deduced from values in column C, on page 82, are from .1 to .2 of a year *less*, and those derived from values in column E are from .2 to .3 of a year *greater*, than corresponding durations obtained by more accurate methods. Arithmetical means of these results exceed the true values by about .05 of a year. By giving greater comparative weight to values deduced from C, closer approximations will ensue.

II. ASTRONOMY.

1. A SIMPLE METHOD OF CORRECTING THE COMMON NAUTICAL METHOD OF "DOUBLE ALTITUDES" OF THE SUN, MOON, OR A PLANET, FOR THE CHANGE OF DECLINATION BETWEEN THE OBSERVATIONS. By PROFESSOR W. CHAUVENET, of the U. S. Naval Academy.

NAVIGATORS who employ, for determining their latitude, two altitudes of the sun, moon, or planet, usually assume the declination as invariable, and equal to the declination at the middle instant between

the two observations; and are content with the result thus obtained. When greater accuracy is desired, either the complete rigorous process of spherical trigonometry must be employed, or a correction must be applied to the abridged process. The latter course is followed by Bowditch in what he gives as his *Third Method of Double Altitudes.* This method consists in applying a correction to one of the altitudes, and employing the declination belonging to the other altitude as the constant declination; and to find the correction, he gives a table with three arguments, which is very embarrassing to the practical seaman. The method I propose supposes the computation carried through by the common process, employing the mean declination; and to the resulting latitude thus found, a small correction is applied, to compute which only two logarithms are required to be taken from the tables in addition to those previously employed. In order to show clearly how this correction is to be obtained, it will be necessary to recapitulate the formulæ which are the analytical expression of the well-known method given by Bowditch as his First Method. Putting

h = first altitude,
h' = second altitude,
δ = mean declination,
λ = difference of the hour-angles of the body at the two observations,
ϕ = approximate latitude,

these formulæ are,

$$\sin A = \cos \delta \sin \tfrac{1}{2} \lambda;$$
$$\sin B = \sin \delta \sec A;$$
$$\sin C = \frac{\cos \frac{1}{2} (h + h') \sin \frac{1}{2} (h - h')}{\sin A};$$
$$\cos Z = \frac{\sin \frac{1}{2} (h + h') \cos \frac{1}{2} (h - h')}{\cos A \cos C};$$
$$\sin \phi = \cos C \sin (B + Z).$$

Now to correct the value of ϕ thus obtained, let

$$\phi' = \text{true latitude} = \phi + \Delta\phi;$$

then I find,

$$\Delta\phi = - \frac{\frac{1}{2} \Delta\delta \sin C}{\cos \phi \sin \frac{1}{2} \lambda},$$

in which $\Delta\delta$ represents the change of declination between the two observations. In the computation of ϕ we have already the logarithms

of sin C and sin $\frac{1}{2}\lambda$, so that we have only to take from the tables the logarithms of $\frac{1}{2}\Delta\delta$ and cos ϕ. It may be necessary to observe to the practical computer, that attention must be paid to the sign of sin C, which will be negative when the second altitude is the greater; and also that $\Delta\delta$ here expresses the increase of declination, towards the north, from the first to the second observation, so that the sign of the correction must be changed when the body is moving towards the south. All the cases of sign are covered by the following simple rule: —

When the second altitude is the greater, apply the correction to the approximate latitude as a NORTHING *or a* SOUTHING, *according as the body is moving towards the* NORTH *or the* SOUTH. *When the first altitude is the greater, apply the correction as a* SOUTHING *or a* NORTHING, *according as the body is moving towards the* NORTH *or the* SOUTH.

It is proper to observe, that this mode of correcting may with sufficient accuracy for nautical purposes be extended to cases where the difference of declinations is two or three degrees, and therefore occasionally to the case where two different bodies are observed, provided their declinations do not differ by more than that quantity.

Finally, when the sun is the body observed, our formula gives the correction in all cases within 1″, and therefore with all the precision required in the most precise determinations on shore with the sextant and artificial horizon.

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2. On a Method of Determining the Latitude of a Place from the observed Times when two known Stars arrive at the same Altitude. By Professor W. Chauvenet, of the U. S. Naval Academy.

The true sidereal times when two stars arrive at the same altitude, and the right ascensions and declinations of the stars, are data sufficient to determine the latitude of the place of observation, the altitude itself remaining wholly unknown.

Gauss's method of finding both the latitude and the clock correction from the observed clock times when *three* stars arrive at the same altitude is well known, but I cannot find that any one has examined the

case where two stars are thus observed, and the clock correction is at least approximately known, though it has very probably occurred to others. Any method, however, which will enable the observer with a sextant to be independent of the errors of his instrument, deserves to be considered. In determining the latitude by meridian observations with the sextant, it is usual to select stars which culminate at nearly the same zenith-distance north and south. The mean of the latitudes found from a pair of stars so selected will be nearly free from errors arising from the eccentricity of the sextant and the imperfect adjustment of the glasses, and from the imperfection of our refraction tables, but will still be liable to the accidental errors of division of the limb. If we confine the observations to the meridian, we can never be *entirely* free from these sources of error, except when the zenith-distances of the two stars are absolutely equal, a condition which can never be satisfied in practice. Since we are limited in sextant observations to the use of bright stars, it often happens that no suitable pair of stars can be found whose meridian zenith-distances differ by less than ten or fifteen degrees, in which case only an imperfect compensation of errors must result. But by observing one or both of the stars off the meridian, we can take them at exactly the same altitude, and thus eliminate all the errors just alluded to. At the same time, however, we introduce another source of error in their stead, namely, imperfect knowledge of the time. A discussion of the formulas (which are very simple) required in the reduction of these observations will serve to show that this new source of error is much less to be feared than the others, and therefore we can claim for the method a decided advantage so far as relates to the elimination of instrumental errors and errors of refraction. Let

σ, σ' = true sidereal times of observation,
α, α' = right ascensions of the two stars,
δ, δ' = declinations of the two stars,
t, t' = hour-angles of the two stars,
h = altitude of either star,
ϕ = latitude of the observer;

then, the hour-angles being found by the equations

$$t = \sigma - \alpha, \qquad t' = \sigma' - \alpha',$$

we have for the two stars

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t,$$
$$\sin h = \sin \phi \sin \delta' + \cos \phi \cos \delta' \cos t'.$$

Subtracting the first of these equations from the second, we find

$$\tan \phi (\sin \delta' - \sin \delta) = \cos \delta \cos t - \cos \delta' \cos t' =$$
$$\tfrac{1}{2}(\cos \delta - \cos \delta')(\cos t + \cos t') + \tfrac{1}{2}(\cos \delta + \cos \delta')(\cos t - \cos t');$$

and resolving the sums and differences into products by the usual formulæ of trigonometry, we readily deduce

$$\tan \phi = \tan \tfrac{1}{2}(\delta' + \delta) \cos \tfrac{1}{2}(t' + t) \cos \tfrac{1}{2}(t' - t)$$
$$+ \cot \tfrac{1}{2}(\delta' - \delta) \sin \tfrac{1}{2}(t' + t) \sin \tfrac{1}{2}(t' - t).$$

To facilitate the computation of this formula, let the auxiliaries A and B be found by the conditions,

$$A \sin B = \sin \tfrac{1}{2}(t' - t) \cot \tfrac{1}{2}(\delta' - \delta); \qquad (1.)$$
$$A \cos B = \cos \tfrac{1}{2}(t' - t) \tan \tfrac{1}{2}(\delta' + \delta);$$

then we have,

$$\tan \phi = A \cos [\tfrac{1}{2}(t' + t) - B]. \qquad (2.)$$

These simple formulæ occur also in the method of finding both time and latitude from three stars according to the method of Gauss above mentioned. But if one of the stars is on the meridian, (and this case would naturally be preferred,) we can resort to a still more simple method of reduction. For if we have $t' = 0$, our fundamental equations, under the form,

$$\sin h = \cos (\phi - \delta) - 2 \cos \phi \cos \delta \sin^2 \tfrac{1}{2} t,$$
$$\sin h = \cos (\phi - \delta'),$$

give

$$\sin [\tfrac{1}{2}(\delta + \delta') - \phi] = \frac{\cos \phi \cos \delta \sin^2 \tfrac{1}{2} t}{\sin \tfrac{1}{2}(\delta' - \delta)};$$

or, for practical use,

$$\sin \gamma = \frac{\cos \phi \cos \delta \sin^2 \tfrac{1}{2} t}{\sin \tfrac{1}{2}(\delta' - \delta)}, \qquad \phi = \tfrac{1}{2}(\delta' + \delta) - \gamma,$$

to compute which an approximate value of the latitude must be known.

To discuss the effect of errors in the time, let ΔT denote the (sidereal) clock correction, which may be assumed to be the same at both observations, the *rate* being duly allowed for. If then T and T' are the clock times of the observations, the errors in the hour-angles will be

$$dt = dT + d.\Delta T,$$
$$dt' = dT' + d.\Delta T',$$

where dT and dT' are the errors of observation, and $d.\Delta T$ the error in the clock correction. We shall have, by differentiating our fundamental equations,

$$dh = -\cos A\, d\phi - \cos\phi \sin A\,(15\,dT) - \cos\phi \sin A\,(15\,d.\Delta T),$$
$$dh' = -\cos A'\, d\phi - \cos\phi \sin A'\,(15\,dT') - \cos\phi \sin A'\,(15\,d.\Delta T),$$

in which A and A' are the azimuths of the stars reckoned from the south point. In these equations we may put $d\,h = d\,h'$, differences of altitude having been already eliminated, and we shall find, by taking the difference of the two equations,

$$\frac{d\,\phi}{15\cos\phi} = -\frac{\sin A}{\cos A - \cos A'}\,dT + \frac{\sin A'}{\cos A - \cos A'}\,dT'$$
$$+ \frac{\sin A' - \sin A}{\cos A - \cos A'}\,d.\Delta T.$$

The coefficient of $d.\Delta T$ is equal to $\cot \frac{1}{2}(A' + A)$, which becomes zero when $\frac{1}{2}(A' + A) = 90°$, that is, when the observations are equally distant from the prime-vertical. The coefficient of dT is equal to

$$\frac{\sin A}{2 \sin \frac{1}{2}(A' + A) \sin \frac{1}{2}(A' - A)};$$

which becomes zero when the stars are both observed on the meridian with a difference of azimuth of 180°. Hence, errors of observation and in the clock correction are the smaller, the nearer the stars are to the meridian, one north and the other south of the zenith.

The coefficient $\cot \frac{1}{2}(A' + A)$ will have the same numerical value, but with opposite signs, if the same stars are observed on both sides of the meridian. The mean of two results obtained from the same pair of stars observed on each side of the meridian, will therefore be entirely free from the effect of a small error in the clock correction. This is an important remark in relation to a method proposed to be carried out with the sextant alone.

For the star very near or on the meridian, an error in the observed time will generally produce but an inappreciable effect. But for the star off the meridian, if we put $A' = 180°$, we have

$$\tfrac{1}{15}\,d\phi = -\frac{\cos\phi \sin A}{1 + \cos A}\,dT = -\cos\phi \tan \tfrac{1}{2} A\, dT.$$

If we suppose an error of 1^s in the observed time, and that the stars are selected so that the azimuth of the star off the meridian is not more than 15°, this formula gives

$$d\phi = -1''.96 \cos \phi.$$

We see, then, that the errors to which this method is liable, when it is judiciously applied, are far within the unavoidable errors resulting from the small optical power of the sextant telescope. It is, however, an objection to it, that, in order to multiply observations on the same stars, much time must be consumed both in the observations and in the computations. I offer it chiefly as completing in some degree the methods available with the sextant, and as being (so far as I am aware) the only method which is wholly free from the errors of that instrument. It may occasionally enable an observer, possessed of only a very poor sextant and a tolerably good watch, to obtain, nevertheless, very accurate results.

The method may be applied also with the zenith telescope, the instrument by which the very accurate determinations of latitude have been made on the Coast Survey. In this case we could not observe the two stars at absolutely the same altitude, but would have to take into account the slight difference of altitude shown by the level readings in the two positions of the instrument. This is easily done, and with great accuracy. By observing the same stars at different places, differences of latitude are found almost wholly free from the errors of the catalogue places of the stars; with the advantage over the method of observing with the zenith telescope only in the meridian, that greater differences of latitude may be measured, and without the use of the micrometer; or, if the micrometer is used, by confining the observations to the vicinity of the middle of the field. This will be obvious to any one acquainted with that instrument. But whether this advantage would compensate for the sacrifice of time and trouble which the method demands, is doubted by the experienced observers of the Coast Survey, to whom the suggestion has already been made, through the able head of that work. I do not think it necessary, therefore, to develop here the modifications which the method would require in such applications; especially as they are mostly of such a nature as to occur to any observer experienced in the use of the zenith telescope. I will only remark, that the method I propose may be applied with an alt-azimuth, theodolite, or universal instrument, or any instrument which is provided with a level arranged in such a manner that it may be clamped at any angle with the axis of the telescope, and which permits a rotation of the telescope and level, thus clamped, around a vertical axis.

3. On a New Method of Measuring Celestial Arcs. By Alvan Clark, of Cambridgeport.

Not a year has yet elapsed since it occurred to me, that an independent movable eye-piece, of high magnifying power, for each image, might be applied with advantage in micrometrical measurements of celestial objects. On giving the subject a careful inspection, I wondered if a plan so natural and simple, and which promised so excellently to my own mind, could have escaped the attention of others. On due inquiry, I found it was really so. With the assistance of my two sons, an instrument of six inches' aperture, with a focal distance of 103 inches, has been already made and mounted. It has a pendulum clock, containing Bond's spring-governor, acting on a sector clamping to the polar axis, which gives an exceedingly equable motion to the telescope, for the space of two hours.

I have thus far used a prism with the eye-pieces, while observing, as affording a more comfortable position. Instead of the spider-line micrometer, I made a cheap dividing-machine, for graduating strips of glass, with a finely pointed diamond. The screw of the machine has sixteen threads to an inch, and an appropriate circle to determine the fractions of a revolution. Kept by the ruling-machine is a constant stock of blank pieces of common plate-glass, about four inches long and three quarters of an inch in width. There are clamps for holding such a strip on the stage or carriage of the ruling-machine, and corresponding springs for securing them under the eye-pieces of the telescope at the proper focal distance. In procuring an observation, the first step is to bring the two images to the centre of their respective fields, with the driving clock at work; then, with common dividers, take the distance between the eye-pieces, which are adjustable in distance to fit the different cases, and with a rule, or by going directly to the machine, find the included number of threads upon the screw; place a blank glass under the diamond, cut first a longitudinal line through the centre, then two cross lines, giving the number of turns to the screw which my measure with the dividers indicated to be necessary between them. This glass is then directly transferred from the machine to its place under the eye-pieces of the telescope, and the lines compared with the stars, by moving the eye

from one eye-piece to the other a number of times. If the space be found too wide or too narrow, another glass is ruled in about two minutes of time, with an estimated allowance for the errors of the first in the reading of the circle upon the screw. In about three or four trials a very close approximation is obtained. Here two persons can be employed with advantage, in turning to account a good hour for work; one constantly at the telescope and the other at the ruling-machine. In getting a series of measures in distance, the former has no reading of circles, or scales, to abstract his attention or occupy his time. His only duty is to take the glasses, one after another, as furnished, compare the distances of the lines with that of the stars, and report them to his co-worker at the machine, who, in turn, must number and keep a record of every glass he rules. He should also record the report on each ruling, at the time it is given. In this way great expedition is secured, and by keeping the one at the telescope uninformed as to the value of all the rulings until the series is completed, obliging him to pronounce on lines slightly, but purposely, misplaced, without a possible bias of judgment, the other, knowing by his record the different values furnished, is able to form a very correct estimate of the accuracy they are obtaining. A great number of observations, taken in this way, have convinced me, that, in tolerable states of atmosphere, it would be impossible for the one at the machine to mislead the assistant at the telescope two tenths of a second, right or left, from a given line. Attempts at such deceptions I have made, series after series, which have been regularly detected, and pointed out, when the weather has afforded any middling opportunity for such work, even with this small instrument. In these cases, none of the objects have been less than thirteen minutes, and in one instance over fifty-five minutes distant.

In measuring angles of position, I proceed as with a spider line, only employing in its stead a diamond line upon glass. I am looking up objects where the two are as nearly equidistant from the ecliptic as possible, and preserve my rulings for future use. For annual parallaxes, this method affords peculiar conveniences, especially where the situations of the objects demand measures of distance rather than angles of position. No question relating to extent of field has any bearing on the magnifying powers an observer may wish to employ, and, if he chooses, he may use a high power upon one object and a

low one upon the other, at the same time. No advantage could possibly be claimed for the two eye-pieces, where objects are so near each other that they come well into the field, of a suitably high power, with one. Carefully conducted and many times repeated experiments have been made for testing the accuracy of measures taken on distant objects with the two, as compared with those taken on the most favorably situated objects with one, the details of which would here be needless. But I will state, I can find no sensible advantage in the one over the other; and if I were seeking a close agreement, in a great number of trials, I should certainly resort to the two eye-pieces, for all distances between three and one hundred minutes. A distortion of the image, more or less, attends the different distances from the optical axis of the telescope which the spaces to be measured may require, though it is nothing seriously objectionable, in intervals of less than one degree. But by making the object-glass on the plan of a camera-obscura used in producing daguerreotype pictures, a mastery of five degrees or more could be secured. A good driving-clock is an important appendage to an equatorial telescope, in using the ordinary filar micrometer; and it will be evident a double necessity for it exists in this case. I would, therefore, again refer to the spring-governor, admitting that no small share of the promise attending this primitive effort is due to Mr. Bond's improvement, and his kind permission to use it in my clock. When first explained, a favorable opinion on his part was expressed upon the proposed plan of observing, which encouraged me to assume the responsibility of putting it to the test, by direct experiment. Thus have I incurred toward my excellent friend a double obligation, in connection with the double eye-piece.

The observations I have to offer, I must admit, are selected, and were made with great care, in choice states of weather; the first on the evening of August 7th, 1856, on α Ophiuchi and a star of the eighth magnitude *preceding;* the other on α Aquilæ and a fifth magnitude *following*, upon the evening of August 10th, 1856. In the first of these cases, eight observations all agree to within less than three tenths of a second, and in the other, five observations agree to within less than two tenths of a second; yet the distances are such that they could not be brought into the field of a suitably high power, with common micrometers, to be measured at all. The observations were

commenced before the stars reached the meridian, and closed when about one hour past, in both cases, so that refraction would make but little show in the work. What might be expected of the instrument, adequate in dimensions, and fitted up with a proper outlay, those professionally engaged in such matters should be able to judge. My optical experiments and labors for the past twelve years have been preying upon my pecuniary resources, so that now they are entirely insufficient for so great an undertaking, whatever might be my ambition for contributing to science, or serving my country. Much time and careful toil have been bestowed on grinding and figuring lenses, and applying them to the search of the heavens; and though the pride of my heart finds its aliment in pointing to a number of exquisitely fine new telescopic objects, you can well understand they have not "put money in my purse." But not the discouraging points attending some of my past humble enterprises, nor approaching age and infirmity, nor absence of needed aid in giving the most potent form to this novel method of making astronomical observations, can cause me to dismiss it, as Dr. Johnson did his Dictionary, "with frigid tranquillity." But I am now planning upon methods which shall be convenient and effective for using with it the spider's web. And if I judge rightly, for a certain class of measures, it will, in due time, be regarded as "a more excellent way."

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4. The Stability of Satellites revolving in Small Orbits. By Daniel Vaughan, of Cincinnati.

The modification which centrifugal force produces on the form of the planets and the gravity at their surfaces has long been a subject of mathematical inquiry; but on the secondary planets a much greater effect arises from the unequal attraction of the central body on their parts. The theory of the tides will enable us to calculate the result of this peculiar action. If the earth could exchange orbits with Jupiter's nearest satellite, without altering its time of rotation, our tidal force would become nearly twenty thousand times as great as it is at present, and a succession of deluges would devastate all our lands. As the

feeble gravity of the satellite is less capable of restraining the disturbance, the commotions would be more dreadful on its surface, unless (as astronomers suppose) the rotation keeps pace with the orbital revolution, so that the same side is always directed to Jupiter. This arrangement, together with the small eccentricity of its orbit, must render the satellite free from destructive tides, whatever relation may subsist between its lands and seas.

The centrifugal force arising from a rotation once in forty-two hours and twenty-seven and a half minutes would diminish the equatorial gravity of the satellite, by its $\frac{1}{1\,8\,4}$ part; and Jupiter's attraction would produce double this diminution on the parts of the surface in conjunction and in opposition with him. The latter force increases polar gravity about one half per cent, and accordingly there will be a difference of more than two per cent between the weight of the same body at the poles and at the points turned to the primary. The deviation from a sphere which is unavoidable would make the difference much greater.

If the same satellite were only one fourth of its present distance from Jupiter, its gravity would be entirely suspended at the parts of its surface in conjunction and in opposition with the latter body; and the planetary structure, which requires the action of gravity in every direction, could no longer be preserved. Even at the distance of ninety thousand miles from the primary, gravity would be so far reduced in these localities as to render the satellite unstable, and to lead to its dismemberment. While, therefore, the laws of motion do not preclude the possibility of planets having matter revolving around them at small distances beyond the confines of their atmospheres, the conditions of equilibrium will render it impossible for this matter to exist in a single undivided mass, either of a spherical or ellipsoidal form.

The rings of Saturn furnish an instance of matter revolving around a centre in a region so dangerous to satellites. While many astronomers have been alarmed for the safety of this planetary girdle, they have overlooked the perils to which a satellite would be exposed if it moved in so small an orbit. At the mean distance of the outer ring, a satellite as dense as Saturn would be incapable of retaining its planetary form; nor could one of double the density revolve in security in the space which the centre of the inner ring occupies. If a resisting

medium should impede celestial movements, each satellite would finally reach the surface of its primary; but, before arriving there, would undergo a dismemberment, and its fragments be permitted to move in independent orbits. It may be shown, however, that these fragments would ultimately have their orbits changed to circles; and that they would acquire and retain an annular form in their revolutions around the central body.

The existence of planetary rings seems therefore to depend on their density and their proximity to the central body, whose attraction renders it impossible that satellites could be formed or preserved in their immediate vicinity. There is also much reason to believe that the rings of Saturn are the remains of two former satellites. The fact that the inner edge of the nearer ring has been constantly approaching the planet since the time of Huyghens, proves that this appendage cannot have existed for a long time in its present condition; and if, as astronomers calculate, it will be united to the planet before a century, the fact of its recent origin will scarcely admit of a doubt. We may assert, however, with more confidence, that the matter composing the rings can never form one or two satellites.

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5. On the Meridian Instruments of the Dudley Observatory. By Dr. B. A. Gould, of Cambridge.

Mr. Gould described the meridian-circle and transit-instrument, now nearly completed for the Dudley Observatory, and gave some account of the principles adopted in their construction.

The meridian instruments now in use in the several observatories of the world may be classified in two divisions, — which may be designated as the German and the English styles, — and perhaps be justly described, the one as the instrument of the engineer, the other as that of the artist. For the former the circles are large and massive, frequently having a diameter equal to the entire focal length of the attached telescope; in the latter they are smaller and slighter. The new transit-circle of Professor Airy, at Greenwich, typifies the English style, and this instrument, with its counterpart at the Cape of

Good Hope, presents the merits in the most conspicuous and impressive form. It is of iron, cast in a single piece; incapable of reversal, for which the observation of collimators is substituted; without a striding or hanging level, this apparatus being superseded by observations of the meridian thread as reflected from the surface of mercury; the circle is eight feet in diameter, and read by diverging microscopes firmly imbedded in a massive pier; and the pivot-forms are investigated by means of a collimating apparatus, of which the axis of rotation itself forms a part.

The instruments of the German school are of an entirely different order, — lighter and more mobile. Their circles are small in comparison with the length of the tube; the microscopes are supported upon a frame concentric with the axis, and form one system, the position of which is known by means of an attached level, whose indications furnish a correction to be applied to the mean of their several readings. The level is used, indeed, whenever its use is possible, and a great part of the precision of the results of observation is dependent upon the delicacy with which this highly trusted instrument may be constructed and used. Frequent reversals of the instrument are deemed indispensable; and in general the structure is devised with a view to easy, rapid and frequent changes in the relative position of all those parts which may be rendered movable. To sum up, — the one class of instruments is designed for securing absolute uniformity of circumstances in all observations; the other, for attaining as great diversity of circumstance as is consistent with the retention of the same degree of accuracy.

The meridian-circle for the Dudley Observatory has been ordered of Messrs. Pistor and Martins, of Berlin, and in its form and the fundamental principles adopted my aim has been to avoid the prejudices of education and the prepossessions of taste, and if possible to exercise an eclectic judgement, using however the greatest care to shun such a composite form as would impair the unity of idea, and fail of the preponderant merit which both the English and the German forms may claim, in being consistent developments of their fundamental idea.

All this seemed not impossible, nor indeed did it seem beyond attainment to combine with such an eclectic form sundry new, and by no means unimportant, additions. This has been the endeavor, and it

remains to be seen how sound may have been the foundation for these hopes and expectations.

The object-glass is from material furnished by Messrs. Chance Brothers, of Birmingham, and made under the supervision of Mr. Masselin. It was my earnest desire that it might be ground and worked into form by some one of our own accomplished artists, but the Berlin mechanicians were unwilling to entertain any proposition of the kind, — desiring to take the whole responsibility, if any, — and were so strenuous that I refrained from pressing the matter. The clear aperture is ninety French lines; the focal length, ten English feet.

Both circles are divided, and capable of rotation round the axis, and they are read by means of four microscopes firmly set in each pier, — horizontal, not converging, although the divided silver limb is slightly oblique to prevent the dazzling image of the lamp from blinding the observer's eye. The piers being two feet in thickness, and the microscopes read from the outer side, these microscopes are not far from twenty-five inches in length, — a circumstance which gives rise to various not unimportant disadvantages; but the ingenuity and skill of Mr. Martins have surmounted the chief of these, the large amount of expansion and contraction of the metal due to changes of temperature, with great success, by leaving the metal tubes free to extend or recede without hindrance, and without affecting either the distance of the lenses or their fixity in the stone.

To obviate the chief disadvantages of attaching the microscopes to the piers, namely, those arising from the unequal changes in the piers themselves, these will be coated with oil, or some other preparation for excluding moisture, wound around with list or baize, and then encased in wood. With these precautions, I am very confident that we are justified in awaiting from this more massive construction greater advantages than would be derived from the metallic connection of the microscopes, although continually subjected to scrutiny by means of the attached ether-level.

The circles are three feet in diameter, and entirely protected on the outer side by the piers. They are of the form which long experience has recommended to Messrs. Pistor and Martins as the best, — not too heavy at the rim, and with radial arms thickening in both dimensions towards the centre. The screen-tubes for the microscopes draw back automatically as soon as the counterpoises are relieved of a portion of

their burden, and it is thus possible to have them very close to the circles, when in use, without incurring any danger of injuring the graduation when the instrument is lifted for reversal.

The eye-piece has a vertical as well as a horizontal motion; and the diaphragm, which is of course adapted for chronographic observation, is provided with both a horizontal and a vertical micrometer, — the former being especially intended for the observation of polar stars, according to the method recently adopted in the Paris Observatory, and which Professor Bache had investigated in 1849.

The method of Hansen for measuring and eliminating the effect of flexure comes from an authority too high, and commends itself too strongly, to justify us in lightly setting it aside. But advantages entirely incompatible with its employment presented themselves in such number as to induce me to accede to the earnest recommendation of the artist, and abandon the original plan of interchangeable eye-piece and object-glass. Some of the decisive arguments, briefly expressed, are the following. It is only when the most absolute symmetry has been attained in every part of the tube and its accessory parts, that the flexure is absolutely determined in this manner; otherwise, we obtain the measure of an ideal, not a real, flexure. Furthermore, not only is the formula which attributes the maximum flexure to the horizontal position, and makes the flexure in other positions a simple function of the altitude, not trustworthy, but I will not hesitate to go farther, and, paradoxical as it may appear, to express my decided conviction that the flexure is not necessarily a maximum for the horizon or minimum for the nadir and zenith, and that in almost every existing instrument, if not all, the flexure is unequal for the same altitude upon different sides of the vertical. The interchange of object-glass and eye-pieces presupposes either the absence of unsymmetrical parts within the tube, such as the apparatus for illumination and the shafts by which we regulate the amount of light admitted, or the disconnection of these from their gearing or screw-heads. Indeed, nothing like the former can be reasonably demanded, — a sacrifice which seems disproportionate to the end to be attained. Moreover, the new meridian-circle is equipped with more than a usual amount of internal mechanism, although the arrangement and support of this latter has been planned with an especial view to avoidance of any prejudicial effect arising from unsymmetric distribution of weight. The measurement

of flexure may take place without disturbing the adjustments or parts of the instrument, by some apparatus analogous to the neat and practical contrivance of Professor Challis, who arranges a pair of collimators in such a manner that they are used in connection with each other at any desired angle of altitude. Moreover, the reversal of the instrument admits of a scrutiny and check upon the determinations, which provides all needful safeguard against erroneous results.

The circles are divided to 2′, and read by microscope to 0″.1. The unit's place of the degree is always visible within the field of the microscope, and the decades of degrees are engraved upon the rim of the circle. The finders read to 10′, and by vernier to 1′.

The axis is turned within as well as without, a precaution upon which I also insisted with regard to the tube. The cube measures thirteen inches and a half on each side, and the pivots are two inches in diameter. The difficulty of obtaining a satisfactory and suitably homogeneous piece of iron for the axis may be estimated from the circumstance that even in Berlin, justly renowned as is that city for knowledge and skill in everything pertaining to the founding of iron, three successive castings had to be rejected before a satisfactory piece could be obtained; and even then it became necessary to deviate from the original plan, — not, however, as I trust, to the disadvantage of the instrument. The weight of the axis is about 350 pounds.

The illumination is entirely by gas, the light designed for the illumination of the field entering by one pivot, and that for the threads by the other. Arrangements are made for illuminating with lights of different colors, and for observing, when occasion requires, with bright threads upon a bright field. The levels are boxed, provided with air-chambers, and read from end to end, not from the middle outwards.

In fine, it has been my endeavor to incorporate in the design of this instrument the principle, — never before attained, so far as I am aware, — that every instrumental correction, without exception, should be capable of determination by two entirely distinct and independent methods; and in this respect also to combine the advantages of the German and the English forms. And I may claim for the new instrument that its errors of graduation, its errors of flexure, collimation, level, azimuth and nadir-point, may all be determined by two separate processes, free from any dependence, direct or indirect, upon each other. And whatever may be its errors of construction or of mounting, there is no fear

that they will escape detection and accurate measurement. So earnest has been my desire to lose none of the advantages on either side of questions upon which experienced astronomers differ in opinion, that no point of detail has been deemed too minute for the application of this idea of duality, and I have even requested the artists to provide one set of microscopes with crosses, after the fashion of Troughton, and the other with close parallel threads, according to the custom of Repsold and the almost universal usage of the German mechanicians.

If this eclectic spirit shall prove to have been successful in attaining its ends without the sacrifice of unity, of artistic or theoretic elegance, of convenience, or of any scientific advantage, the care and labor bestowed upon the decision of the principles which should rule its design will be more than rewarded. But here, as in all instruments of a high order, it is the mechanical artist to whom most of the success is due, and to whose refined delicacy of judgment, taste, and skill we must thank the chief advances of modern astronomy. Bessel once said that he could determine the place of a star with a musket-barrel and a cart-wheel. Few things were impossible to Bessel, but you will agree with me that at any rate even a Bessel would with such appliances hardly have determined so large a number of precise star-positions as, thanks to the genius of Fraunhofer, Reichenbach and Repsold, are contained in those noble Königsberg volumes, and are sufficient to render the names of the artist and the astronomer alike immortal.

It is my privilege, on this occasion, to become the organ of the Trustees of the Observatory in announcing that, at the instigation of the Scientific Council, they have given to the new meridian-circle which I have been describing, — which, in the grandeur of its dimensions, is rivaled only by the renowned and gigantic transit-circle of the Royal Observatory at Greenwich, and which, as we are trusting, may prove to be a forward step in instrumental astronomy, — a name which will render the exquisite instrument still more a source of pride to Albany and to the Dudley Observatory, — a name full of associations of disinterested and unassuming liberality, of generous public spirit, — the name of a man who knows no guile, a citizen of large, expanded mind and heart, whose efforts have, under the blessing of a favoring Providence, resulted in an affluence by which all around him are made happy, and without whose constant effort, protecting care, and wise counsel, neither this instrument, nor the Observatory for which it is

designed, would ever have existed. The Trustees have authorized me to announce, that, in token of their respect for Thomas W. Olcott, of Albany, the instrument will be known as the Olcott Meridian-Circle, and that the name is already engraved upon the telescope at Berlin.

The transit-instrument is similar to the meridian-circle, so far as the latter is an instrument for the measurement of right ascension. It is the property of the Coast Survey of the United States, whose enlightened chief has authorized its employment at the Dudley Observatory for the present. The object-glass has a clear aperture of 72 French lines, and a focal length of 8 feet.

In both these instruments the Ys are so constructed that the level-arm may rest upon that part of the pivot which supports the instrument.

III. PHYSICS AND CHEMISTRY.

1. On Acoustics applied to Public Buildings. By Professor Joseph Henry, of Washington, D. C.

At the meeting of the American Association in 1854, I gave a verbal account of a plan of a lecture-room adopted for the Smithsonian Institution, with some remarks on Acoustics as applied to apartments intended for public speaking. At that time the room was not finished, and experience had not proved the truth of the principles on which the plan had been designed. Since then the room has been employed two winters for courses of lectures to large audiences; and I believe it is the general opinion of those who have been present, that the arrangements for seeing and hearing, considering the size of the apartment, are entirely unexceptionable. The room has fully answered all the expectations which were formed in regard to it, previous to its construction. The origin of the plan was as follows.

Professor Bache and myself had directed our attention to the subject of acoustics as applied to buildings, and had studied the peculiarities in this respect of the hall of the House of Representatives, when the President of the United States referred to us for examination the plans proposed by Captain Meigs of the Engineer Corps, U. S. A., for

the rooms about to be constructed under his direction in the new wings of the Capitol. After visiting with Captain Meigs the principal halls and churches of the cities of Philadelphia, New York, and Boston, we reported favorably on the general plans proposed by him, and which were subsequently adopted.

The facts which we have collected on this subject may be referred to a few well-established principles of acoustics, which have been applied in the construction of the Smithsonian lecture-room. To apply them generally, however, in the construction of public halls, required a series of preliminary experiments.

In a very small apartment it is an easy matter to be heard distinctly at every point; but in a large room, unless from the first, in the original plan of the building, provision be made, on acoustic principles, for a suitable arrangement, it will be difficult, and indeed in most cases impossible, to produce the desired effect. The same remark may be applied to lighting, heating, and ventilation, and to all the special purposes to which a particular building is to be applied. I beg, therefore, to make some preliminary remarks on the architecture of buildings, bearing upon this point, which, though they may not meet with universal acceptance, will, I trust, commend themselves to the common sense of the public in general.

In the erection of a building, the uses to which it is to be applied should be clearly understood, and provision definitely made, in the original plan, for every desired object.

Modern architecture is not, like painting or sculpture, a fine art, *par excellence*. The object of these latter is to produce a moral emotion, — to awaken the feelings of the sublime and the beautiful; and we greatly err when we apply their productions to a merely utilitarian purpose. To make a fire-screen of Rubens's Madonna, or a candelabrum of the Apollo of Belvidere, would be to debase those exquisite productions of genius, and do violence to the feelings of the cultivated lover of art. Modern buildings are made for other purposes than artistic effect, and in them the æsthetical must be subordinate to the useful; though the two may coexist, and an intellectual pleasure be derived from a sense of adaptation and fitness, combined with a perception of harmony of parts, and the beauty of detail.

The buildings of a country and an age should be ethnological expressions of the wants, habits, arts, and feelings of the time in

which they were erected. Those of Egypt, Greece, and Rome were intended, at least in part, to transmit to posterity, without the art of printing, an idea of the character of the periods in which they were erected. It was by their monuments that these nations sought to convey an idea of their religious and political sentiment to future ages.

The Greek architect was untrammelled by any condition of utility. Architecture was with him in reality a fine art. The temple was formed to gratify the tutelar deity. Its minutest parts were exquisitely finished, since nothing but perfection on all sides and in the smallest particulars could satisfy an all-seeing and critical eye. It was intended for external worship, and not for internal use. It was without windows, entirely open to the sky, or, if closed with a roof, the light was merely admitted through a large door. There were no arrangements for heating or ventilation. The uses, therefore, to which, in modern times, buildings of this kind can be applied, are exceedingly few; and though they were objects of great beauty, and fully realized the intention of the architect by whom they were constructed, yet they cannot be copied in our day without violating the principles which should govern architectural adaptation.

Every vestige of ancient architecture which now remains on the face of the earth should be preserved with religious care; but to servilely copy these, and to attempt to apply them to the uses of our day, is as preposterous as to endeavor to harmonize the refinement and civilization of the present age with the superstition and barbarity of the times of the Pharaohs. It is only when a building expresses the dominant sentiment of an age, when a perfect adaptation to its use is joined to harmony of proportions and an outward expression of its character, that it is entitled to our admiration. It has been aptly said, that it is one thing to adopt a particular style of architecture, but a very different one to *adapt* it to the purpose intended.

Architecture should change not only with the character of the people, and in some cases with the climate, but also with the material to be employed in construction. The use of iron and of glass requires an entirely different style from that which sprung from the rocks of Egypt, the masses of marble with which the lintels of the Grecian temples were formed, or the introduction of brick by the Romans.

The great tenacity of iron, and its power of resistance to crushing,

should suggest for it, as a building material, a far more slender and apparently lighter arrangement of parts. An entire building of iron, fashioned in imitation of stone, might be erected at small expense of invention on the part of the architect, but would do little credit to his truthfulness or originality. The same may be said of our modern pasteboard edifices, in which, with their battlements, towers, pinnacles, "fretted roofs and long drawn aisles," cheap and transient magnificence is produced by painted wood or decorated plaster. I must not, however, indulge in remarks of this kind, but must curb my feelings on the subject, since I speak from peculiar experience.

But to return to the subject of acoustics, as applied to apartments intended for public speaking. While sound, in connection with its analogies to light, and in its abstract principles, has been investigated within the last fifty years with a rich harvest of results, few attempts have been successfully made to apply these principles to practical purposes. Though we may have a clear conception of the simple operation of a law of nature, yet when the conditions are varied, and the actions multiplied, the results frequently transcend our powers of logic, and we are obliged to appeal to experiment and observation to assist in deducing new consequences, as well as to verify those which have been arrived at by mathematical deduction. Furthermore, though we may know the manner in which a cause acts to produce a given effect, yet in all cases we are obliged to resort to actual experiment to ascertain the measure of effect under given conditions.

The science of acoustics as applied to buildings, perhaps more than any other, requires this union of scientific principles with experimental deductions. While, on the one hand, the application of simple deductions from the established principles of acoustics would be unsafe from a want of knowledge of the constants which enter into our formulæ, on the other hand, empirical data alone are, in this case, entirely at fault, and of this any person may be convinced who will examine the several works written on acoustics by those who are deemed practical men.

Sound is a motion of matter capable of affecting the ear with a sensation peculiar to that organ. It is not in all cases simply a motion of the air, for there are many sounds in which the air is not concerned; for example, the impulses which are conveyed along a rod of wood from a tuning-fork to the teeth. When a sound is produced by a

single impulse, or an approximation to a single impulse, it is called a noise; when by a series of impulses, a continued sound, &c.; if the impulses are equal in duration among themselves, a musical sound. This has been illustrated by a quill striking against the teeth of a wheel in motion. A single impulse from one tooth is a noise, from a series of teeth in succession a continued sound; and if all the teeth are at equal distances, and the velocity of the wheel is uniform, then a musical note is the result. Each of these sounds is produced by the human voice, though they apparently run into each other. Usually, however, in speaking, a series of irregular sounds of short duration are emitted, —each syllable of a word constitutes a separate sound of appreciable duration, and each compound word and sentence an assemblage of such sounds. It is astonishing, that, in listening to a discourse, the ear can receive so many impressions in the space of a second, and that the mind can take cognizance of and compare them.

That a certain force of impulse, and a certain time for its continuance, are necessary to produce an audible impression on the ear, is evident; but it may be doubted whether the impression of a sound on this organ is retained appreciably longer than the continuance of the impulse itself; certainly it is not retained the $\frac{1}{10}$th of a second. If this were the case, it is difficult to conceive why articulated discourse, which so pre-eminently distinguishes man from the lower animals, should not fill the ear with a monotonous hum; but whether the ear continues to vibrate, or whether the impression remains a certain time on the sensorium, it is certain that no sound is ever entirely instantaneous, or the result of a single impression, particularly in enclosed spaces. The impulse is not only communicated to the ear, but to all bodies around, which, in turn, themselves become centres of reflected impulses. Every impulse must give rise to a forward, and afterwards to a return, or backward, motion of the atom.

Sound from a single explosion in air, equally elastic on all sides, tends to expand equally in every direction; but when the impulse is given to the air in a single direction, though an expansion takes place on all sides, yet it is much more intense in the line of the impulse. For example, the impulse of a single explosion, like that of the detonation of a bubble of oxygen and hydrogen, is propagated equally in all directions, while the discharge of a cannon, though heard on every side, is much louder in the direction of the axis; so also

a person speaking is heard much more distinctly directly in front than at an equal distance behind. Many experiments have been made on this point, and I may mention those repeated in the open space in front of the Smithsonian Institution. In a circle, 100 feet in diameter, the speaker in the centre, and the hearer in succession at different points of the circumference, the voice was heard most distinctly directly in front, gradually less so on either side, until, in the rear, it was scarcely audible. The ratio of distance for distinct hearing directly in front, on the sides, and in the rear, was about as 100, 75, and 30. These numbers may serve to determine the form in which an audience should be arranged in an open field, in order that those on the periphery of the space may all have a like favorable opportunity of hearing, though it should not be recommended as the interior form of an apartment, in which a reflecting wall would be behind the speaker.

The impulse producing sound requires time for its propagation, and this depends upon the intensity of repulsion between the atoms, and, secondly, on the specific gravity of the matter itself. If the medium were entirely rigid, sound would be propagated instantaneously; the weaker the repulsion between the atoms, the greater will be the time required to transmit the motion from one to the other; and the heavier the atoms, the greater will be the time required for the action of a given force to produce in them a given amount of motion. Sound also, in meeting an object, is reflected in accordance with the law of light, making the angle of incidence equal to the angle of reflection. The tendency, however, to divergency in a single beam of sound, appears to be much greater than in the case of light. The law, nevertheless, appears to be definitely followed in the case of all beams that are reflected in a direction near the perpendicular. It is on the law of propagation and reflection of sound that the philosophy of echo depends. Knowing the velocity of sound, it is an easy matter to calculate the interval of time which must elapse between the original impulse and the return of the echo. Sound moves at the rate of 1125 feet in a second, at the temperature of 60°.*

* From the average of all the experiments, according to Sir John Herschel, the velocity of sound is 1090 feet at the temperature of 32°, and this is increased 1.14 feet for every degree of temperature of Fahrenheit's scale.

If, therefore, we stand at half this distance before a wall, the echo will return to us in one second. It is, however, a fact known from universal experience, that no echo is perceptible from a near wall, though in all cases one must be sent back to the ear. The reason of this is, that the ear cannot distinguish the difference between similar sounds, as, for example, that from the original impulse and its reflection, if they follow each other at less than a given interval, which can only be determined by actual experiment; and as this is an important element in the construction of buildings, the attempt was made to determine it with some considerable degree of accuracy. For this purpose the observer was placed immediately in front of the wall of the west end of the Smithsonian building, at the distance of 100 feet; the hands were then clapped together. A distinct echo was perceived; the difference between the time of the passage of the impulse from the hand to the ear, and that from the hand to the wall and back to the ear, was sufficiently great to produce two entirely distinct impressions. The observer then gradually approached the building, until no echo or perceptible prolongation of the sound was observed. By accurately measuring this distance, and doubling it, we find the interval of space within which two sounds may follow each other without appearing separately. But if two rays of sound reach the ear after having passed through distances the difference between which is greater than this, they produce the effect of separate sounds. This distance we have called the *limit of perceptibility* in terms of space. If we convert this distance into the velocity of sound, we ascertain the limit of perceptibility in time.

In the experiment first made with the wall, a source of error was discovered in the fact that a portion of the sound returned was reflected from the cornice under the eaves, and as this was at a greater distance than the part of the wall immediately perpendicular to the observer, the moment of the cessation of the echo was less distinct. In subsequent experiments with a louder noise, the reflection was observed from a perpendicular surface of about 12 feet square, and from this more definite results were obtained. The limit of the distance in this case was about 30 feet, varying slightly, perhaps, with the intensity of the sound and the acuteness of different ears. This will give about the sixteenth part of a second as the limit of time necessary for the ear to separately distinguish two similar sounds. From

this experiment we learn that the reflected sound may tend to strengthen the impression, or to confuse it, according as the difference of time between the two impressions is greater or less than the limit of perceptibility. An application of the same principle gives us the explanation of some phenomena of sound which have been considered mysterious. Thus, in the reflection of an impulse from the edge of a forest of trees, each leaf properly situated within a range of 30 feet of the front plane of reflection will conspire to produce a distinct echo, and these would form the principal part of the reflecting surfaces of a dense forest, for the remainder would be screened; and being at a greater distance, any ray which might come from them would serve to produce merely a low continuation of the sound.

On the same principle, we may at once assert that the panelling of a room, or even the introduction of reflecting surfaces at different distances, will not prevent the echo, provided they are in parallel planes, and situated, relatively to each other, within the limit of perceptibility.

Important advantage may be taken of the principle of reflection of sound by the proper arrangement of the reflecting surfaces behind the speaker. We frequently see in churches, as if to diminish the effect of the voice of the preacher, a mass of drapery placed directly in the rear of the pulpit. However important this may be in an æsthetical point of view, it is certainly at variance with correct acoustic arrangements, — the great object of which should be to husband every articulation of the voice, and to transmit it unmingled with other impulses, and with as little loss as possible, to the ears of the audience.

Another effect of the transmission and reflection of sound is that which is called reverberation, which consists of a prolonged musical sound, and is much more frequently the cause of indistinctness of perception of the articulations of the speaker than the simple echo.

Reverberation is produced by the repeated reflection of a sound from the walls of the apartment. If, for example, a single detonation takes place in the middle of a long hall with naked and perpendicular walls, an impulse will pass in each direction, will be reflected from the walls, cross each other again at the point of origin, be again reflected, and so on until the original impulse is entirely absorbed by the solid materials which confine it. The impression will be retained upon the ear during the interval of the transmission past it of two successive waves, and thus a continued sound will be kept up, particularly if the walls of any part

of the room are within 30 feet of the ear. If a series of impulses, such as that produced by the rapid snaps of a quill against the teeth of a wheel, be made in unison with the echoes, a continued musical sound will be the result. Suppose the wheel to be turned with such velocity as to cause a snap at the very instant the return echo passes the point at which the apparatus is placed, the second sound will combine with the first, and thus a loud and sustained vibration will be produced. It will be evident from this that every room has a key-note, and that, to an instrument of the proper pitch, it will resound with great force. It must be apparent, also, that the continuance of a single sound, and the tendency to confusion in distinct perception, will depend on several conditions; — first, on the size of the apartment; secondly, on the strength of the sound or the intensity of the impulse; thirdly, on the position of the reflecting surfaces; and fourthly, on the nature of the material of the reflecting surfaces.

In regard to the first of these, — the larger the room, the longer time will be required for the impulse along the axis to reach the wall; and if we suppose that at each collision a portion of the original force is absorbed, it will require double the time to totally extinguish it in a room of double the size, because, the velocity of sound being the same, the number of collisions in a given time will be inversely as the distance through which the sound has to travel.

Again, that it must depend upon the loudness of the sound, or the intensity of the impulse, must be evident, when we consider that the cessation of the reflections is due to the absorption of the walls, or to irregular reflection, and that, consequently, the greater the amount of original disturbance, the longer will be the time required for its complete extinction. This principle was abundantly shown by our observations on different rooms.

Thirdly, the continuance of the resonance will depend upon the position of the reflecting surfaces. If these are not parallel to each other, but oblique, so as to reflect the sound, not to the opposite, but to the adjacent wall, without passing through the longer axis of the room, it will evidently be sooner absorbed. Any obstacle, also, which may tend to break up the wave, and interfere with the reflection through the axis of the room, will serve to lessen the resonance of the apartment. Hence, though the panelling, the ceiling, and the introduction of a variety of oblique surfaces, may not prevent an isolated echo, provided

the distance be sufficiently great, and the sound sufficiently loud, yet that they do have an important effect in stopping the resonance is evident from theory and experiment. In a room 50 feet square, in which the resonance of a single intense sound continued six seconds, when cases and other objects were placed around the wall, its continuance was reduced to two seconds.

Fourthly, the duration of the resonance will depend upon the nature of the material of the wall. A reflection always takes place at the surface of a new medium, and the amount of this will depend upon the elastic force or power to resist compression and the density of the new medium. For example, a wall of nitrogen, if such could be found, would transmit nearly the whole of a wave of sound in air, and reflect but a very small portion; a partition of tissue-paper would produce nearly the same effect. A polished wall of steel, however, of sufficient thickness to prevent yielding, would reflect, for practical purposes, all the impulses through the air which might fall upon it. The rebound of the wave is caused, not by the oscillation of the wall, but by the elasticity and mobility of the air. The striking of a single ray of sound against a yielding board would probably increase the loudness of the reverberation, but not its continuance. On this point a series of experiments were made by the use of the tuning-fork. In this instrument, the motion of the foot and of the two prongs gives a sonorous vibration to the air, which, if received upon another tuning-fork of precisely the same size and form, would reproduce the same vibrations.

It is a fact well established by observation, that when two bodies are in perfect unison, and separated from each other by a space filled with air, vibrations of the one will be transmitted to the other. From this consideration, it is probable that relatively the same effect ought to be produced in transmitting immediately the vibration of a tuning-fork to a reflecting body, as to duration and intensity, as in the case of transmission through air. This conclusion is strengthened by floating a flat piece of wood on water in a vessel standing upon a sounding-board; placing a tuning-fork on the wood, the vibrations will be transmitted to the board through the water, and sounds will be produced of the same character as those emitted when the tuning-fork is placed directly upon the board.

A tuning-fork suspended from a fine cambric thread, and vibrated in air, was found, from the mean of a number of experiments, to con-

tinue in motion 252 seconds. In this experiment, had the tuning-fork been in a perfect vacuum, suspended without the use of a string, and, further, had there been no ethereal medium, the agitation of which would give rise to light, heat, electricity, or some other form of ethereal motion, the fork would have continued its vibration for ever.

The fork was next placed upon a large, thin pine board, — the top of a table. A loud sound in this case was produced, which continued less than *ten* seconds. The whole table as a system was thrown into motion, and the sound produced was as loud on the under side as on the upper side. Had the tuning-fork been placed against a partition of this material, a loud sound would have been heard in the adjoining room; and this was proved by sounding the tuning-fork against a door leading into a closed closet. The sound within was apparently as loud as that without.

The rapid decay of sound in this case was produced by so great an amount of the motive power of the fork being communicated to a large mass of wood. The increased sound was due to the increased surface. In other words, the shortness of duration was compensated for by the greater intensity of effect produced.

The tuning-fork was next placed upon a circular slab of marble, about three feet in diameter and three quarters of an inch thick. The sound emitted was feeble, and the undulations continued *one hundred and fifteen* seconds, as deduced from the mean of six experiments.

In all these experiments, except the one in a vacuum, the time of the cessation of the motion of the tuning-fork was determined by bringing the mouth of a resounding cavity near the end of the fork; this cavity, having previously been adjusted to unison with the vibrations of the fork, gave an audible sound when none could be heard by the unaided ear.

The tuning-fork was next placed upon a cube of India-rubber, and this upon the marble slab. The sound emitted by this arrangement was scarcely greater than in the case of the tuning-fork suspended from the cambric thread, and, from the analogy of the previous experiments, we might at first thought suppose the time of duration would be great; but this was not the case. The vibrations continued only about forty seconds. The question may here be asked, What became of the impulses lost by the tuning-fork? They were neither transmitted through the India-rubber, nor given off to the air in the form of

sound, but were probably expended in producing a change in the matter of the India-rubber, or were converted into heat, or both. Though the inquiry did not fall strictly within the line of this series of investigations, yet it was of so interesting a character in a physical point of view to determine whether heat was actually produced, that the following experiment was made.

A cylindrical piece of India-rubber, about an inch and a quarter in diameter, was placed in a tubulated bottle with two openings, one near the bottom and the other at the top. A stuffing-box was attached to the upper, through which a metallic stem, with a circular foot to press upon the India-rubber, was made to pass air-tight. The lower tubular was closed with a cork, in a perforation of which a fine glass tube was cemented. A small quantity of red ink was placed in the tube to serve as an index. The whole arrangement thus formed a kind of air-thermometer, which would indicate a certain amount of change of temperature in the enclosed air. On the top of the stem, the tuning-fork was screwed, and consequently its vibrations were transmitted to the rubber within the bottle. The glass was surrounded with several coatings of flannel, to prevent the influence of external temperature. The tuning-fork was then sounded, and the vibrations were kept up for some time. No reliable indications of an increase of temperature were observed. A more delicate method of making the experiment next suggested itself. The tube containing the drop of red ink, with its cork, was removed, and the point of a compound wire formed of copper and iron was thrust into the substance of the rubber, while the other ends of the wire were connected with a delicate galvanometer. The needle was suffered to come to rest, the tuning-fork was then vibrated, and its impulses transmitted to the rubber. A very perceptible increase of temperature was the result. The needle moved through an arc of from one to two and a half degrees. The experiment was varied, and many times repeated; the motions of the needle were always in the same direction, namely, in that which was produced when the point of the compound wire was heated by momentary contact with the fingers. The amount of heat generated in this way is, however, small, and indeed, in all cases in which it is generated by mechanical means, the amount evolved appears very small in comparison with the labor expended in producing it. Jule has shown that the mechanical energy generated in a pound weight, by

falling through a space of seven hundred and fifty feet, elevates the temperature of a pound of water one degree.

It is evident that an object like India-rubber actually destroys a portion of the sound, and hence, in cases in which entire non-conduction is required, this substance can probably be employed with perfect success.

The tuning-fork was next pressed upon a solid brick wall, and the duration of vibration from a number of trials was eighty-eight seconds. Against a wall of lath and plaster the sound was louder, and continued only eighteen seconds.

From these experiments we may infer that, if a room were lined with wainscot of thin boards, and a space left between the wall and the wood, the loudness of the echo of a single noise would be increased, while the duration of the resonance would be diminished. If, however, the thin board were glued or cemented in solid connection to the wall, or embedded in the mortar, then the effect would be a feeble echo, and a long continued resonance, similar to that from the slab of marble. This was proved by first determining the length of continuance of the vibrations of a tuning-fork on a thin board, which was afterwards cemented to a flat piece of marble.

A series of experiments were next commenced with reference to the actual reflection of sound. For this purpose a parabolic mirror was employed, and the sound from a watch received on the mouth of a hearing-trumpet, furnished with a tube for each ear. The focus was near the apex of the parabola, and when the watch was suspended at this point, it was six inches within the plane of the outer circle of the mirror. In this case the sound was confined at its origin, and prevented from expanding. No conjugate focus was produced, but, on the contrary, the rays of light, when a candle was introduced, constantly diverged. The ticking of the watch could not be heard at all when the ear was applied to the outside of the mirror, while directly in front it was distinctly heard at the distance of thirty feet, and with the assistance of the ear-trumpet, at more than double that distance. When the watch was removed from the focus, the sound ceased to be audible. This method of experimenting admits of considerable precision, and enables us directly to verify, by means of sound transmitted through air, the results anticipated in the previous experiments. A piece of tissue-paper placed within the mirror, and

surrounding the watch without touching it, slightly diminished the reflection. A single curtain of flannel produced a somewhat greater effect, though the reflecting power of the metallic parabola was not entirely masked by three thicknesses of flannel; and, I presume, very little change would have been perceived, had the reflector been lined with flannel glued to the surface of the metal. The sound was also audible at the distance of ten feet, when a large felt hat, without stiffening, was interposed between the watch and the mirror. Care was taken in these experiments so to surround the watch, that no ray of sound could pass directly from it to the reflecting surface.

With a cylindrical mirror, having a parabolic base, very little increased reflection was perceived. The converging beams in this case were merely in a single plane, perpendicular to the mirror, and passing through the ear, while to the focal point of the spherical mirror a solid cone of rays was sent.

The reflection from the cylindrical mirror forms what is called a *caustic* in optics, while that from a spherical mirror gives a true focus, or, in other words, collects the sounds from all parts of the surface, and conveys them to one point of space. These facts furnish a ready explanation of the confusion experienced in the Hall of Representatives, which is surmounted by a dome, the under surface of which acts as an immense concave mirror, reflecting to a focus every sound which ascends to it, leaving other points of space deficient in sonorous impulses.

Water, and all liquids which offer great resistance to compression, are good reflectors of sound. This may be shown by the following experiment. When water is gradually poured into an upright cylindrical vessel, over the mouth of which a tuning-fork is vibrated, until it comes within a certain distance of the mouth, it will reflect an echo in unison with the vibrations of the fork, and produce a loud resonance. This result explains the fact, which had been observed with some surprise, that the duration of the resonance of a newly plastered room was not perceptibly less than that of one which had been thoroughly dried.

There is another principle of acoustics which has a bearing on this subject. I allude to the refraction of sound. It is well known that, when a ray of sound passes from one medium to another, a change in velocity takes place, and consequently a change in the direction or a

refraction, must be produced. The amount of this can readily be calculated where the relative velocities are known. In rooms heated by furnaces, and in which streams of heated air pass up between the audience and speaker, a confusion has been supposed to be produced, and distinct hearing interfered with, by this cause. Since the velocity of sound in air at 32° of Fahrenheit has been found to be 1090 feet in a second, and since the velocity increases 1.14 feet for every degree of Fahrenheit's scale, if we know the temperature of the room, and that of the heated current, the amount of angular refraction can be ascertained. But since the ear does not readily judge of the difference of direction of two sounds emanating from the same source, and since two rays do not confuse the impression which they produce upon the ear, though they arrive by very different routes, provided they are within the limit of perceptibility, we may therefore conclude that the indistinctness produced by refraction is comparatively little. Professor Bache and myself could perceive no difference in distinctness in hearing from rays of sound passing over a chandelier of the largest size, in which a large number of gas jets were in full combustion. The fact of disturbance from this cause, however, if any exist, may best be determined by the experiment with a parabolic mirror and the hearing-trumpet before described.

These researches may be much extended: they open a field of investigation equally interesting to the lover of abstract science and to the practical builder; and I hope, in behalf of the committee, to give some further facts with regard to this subject at another meeting.

I will now briefly describe the lecture-room which has been constructed in accordance with the facts and principles previously stated, so far at least as they could be applied.

There was another object kept in view in the construction of this room besides the accurate hearing, namely, the distinct seeing. It was desirable that every person should have an opportunity of seeing the experiments which might be performed, as well as of hearing distinctly the explanation of them.

By a fortunate coincidence of principle, it happens that the arrangements for insuring unobstructed sight do not interfere with those necessary for distinct hearing.

The law of Congress authorizing the establishment of the Smithsonian Institution directed that a lecture-room should be provided; and

accordingly in the first plan one half of the first story of the main building was devoted to this purpose. It was found, however, impossible to construct a room on acoustic principles in this part of the building, which was necessarily occupied by two rows of columns. The only suitable place which could be found was therefore on the second floor. The main building is two hundred feet long and fifty feet wide; but by placing the lecture-room in the middle of the story a greater width was obtained by means of the projecting towers. The general form and arrangement of the room will be understood from the accompanying drawing.

It is one hundred feet from A to B, and on the ground floor seventy-five feet from C to D. E F represents a small gallery in a projection into the rear tower. The main gallery is in the form of a horseshoe, and occupies three sides of the room. The speaker's platform is placed between two oblique walls, H I J K. The corners of the room which are cut off by these walls afford recesses for the stairs into the galleries. The opposite corners are also partitioned off, so as to afford recesses for the same purpose.

The ceiling is twenty-five feet high, and therefore within the limit of perceptibility. It is perfectly smooth and unbroken, with the exception of an oval opening nearly over the speaker's platform, through which light is admitted.

The seats are arranged in curves, and were intended to rise in accordance with the *panoptic curve*, originally proposed by Professor Bache, which enables each individual to see over the head of the person immediately in front of him. The original form of the room, however, did not allow of this intention being fully realized, and therefore the rise is somewhat less than the curve would indicate. The general appearance of the room is somewhat fan-shaped, and the speaker is placed as it were in the mouth of an immense trumpet. The sound directly from his voice, and that from reflection immediately behind him, is thrown forward upon the audience; and as the difference of distance travelled by the two rays is much within the limit of perceptibility, no confusion is produced by direct and reflected sound.

No echo is given off from the ceiling, for this is also within the limit of perceptibility, while it assists the hearing in the gallery by the reflection to that place of the oblique rays.

Again, on account of the oblique walls behind the speaker, and the multitude of surfaces, including the gallery, pillars, stair-screens, &c., as well as the audience, directly in front, all reverberation is stopped.

The walls behind the speaker are composed of lath and plaster, and therefore have a tendency to give a more intense, though less prolonged, sound than if of solid masonry. They are also intended for exhibiting drawings to the best advantage.

The architecture of this room is due to Captain Alexander, of the corps of Topographical Engineers. He fully appreciated all the principles of sound which I have given, and varied his plans until all the required conditions, as far as possible, were fulfilled.

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2. Account of a large Sulphuric-Acid Barometer in the Hall of the Smithsonian Institution. By Professor Joseph Henry, of Washington, D. C.

The opinion has been frequently advanced, that a barometer in which the material used to balance the pressure of the atmosphere is of less specific gravity than mercury, and consequently of a wider range of fluctuation, might throw some new light on several important points of Meteorology. The fluid usually proposed for this purpose has been oil or water; the viscid character of the former, and its tendency to a change of condition, has induced a preference for the latter. Several water-barometers have accordingly been constructed; but, as far as I am informed, the indications of the instruments have not been reliable.

Mariotte used one of this character; also Otto von Guericke constructed a philosophical toy, to which he gave the name of anemoscope, or *semper virum*, on the principle of a water-barometer. It consisted of a tube more than thirty feet high, elevated on a long wall, and terminated by a tall and rather wide glass cylinder, hermetically sealed, in which was placed a toy in the shape of a man. All the tube except a portion of the cylindrical part was concealed behind the wainscoting, and consequently the little image made its appearance only in fine weather.

A water-barometer was constructed by Professor Daniell, and

placed in the hall of the Royal Society, of which a full account has been published in the Transactions of that institution. A minute account is given of the method of blowing the tube, and the details of permanently fastening it in the box which was to form the case. The tube was left open at both ends; to the upper one a stop-cock was attached, and the lower one was inserted in a small steam-boiler, which served the purpose of boiling the water, to expel all the air, of elevating it to the proper height by means of the elastic force of the steam, and also as a permanent cistern to the barometer. After the water was forced to the top and issued from the stop-cock in a jet, the latter was closed; the stop-cock in the boiler was opened, steam suffered to escape, and the water to settle in the tube until balanced by the pressure of air. The upper part of the glass under the stop-cock, which had previously been drawn out into a fine tube, was gradually heated by a blow-pipe, and as soon as it was sufficiently softened the pressure of the air effectually closed it. The part above the stop-cock was then removed with a file. This barometer was completed, after adjusting the scale, by pouring a quantity of castor-oil on the surface of the water to prevent contact with the air.

After a series of observations, however, it was found in the course of about three months that the column of water was gradually descending, and it was finally resolved to open the boiler and to examine the instrument. The oil upon the surface was found to have undergone a change, though the water below was perfectly bright and transparent. A portion of the water was taken out and placed under the receiver of an air-pump, and bubbles of air in abundance were extricated; the air was absorbed by the water, diffused through the whole mass to the top, where it was given off to the vacuum, and thus caused the gradual descent of the column. It was however found it was not atmospheric air in the vacuum, but nearly pure nitrogen; the oxygen had been absorbed in passing through the oil, producing rancidity and other changes in that liquid.

It was evident from this experiment, that oil was not impervious to air. Another attempt to remedy this defect of the instrument was made by using a thin film of gutta-percha, to be left after the evaporation of the naphtha in which it had been dissolved.

An objection, however, to the use of water as the liquid for the barometer, is the vapor which it always gives off, and of which the tension cannot readily be determined. In a glass vessel, in which a

cup of water is enclosed, Professor Espy informs me that he has found the dew-point always less than that which would be due to the temperature.

Desiring to fit up a barometer on a large scale, as one of the objects of interest and use in the Smithsonian Institution, I consulted my friend Professor Schaeffer of the Patent Office as to the best liquid to be employed. He advised the use of sulphuric acid, but I did not immediately adopt this advice, on account of the apparently dangerous character of this substance. Happening, however, some time afterwards to be speaking on the subject of barometers with Mr. James Green, the instrument-maker, in the presence of Professor Ellet of New York, the latter asked why I did not have a large one constructed with sulphuric acid. The suggestion having thus again been independently made, and Mr. Green expressing his willingness to undertake the work, I gave the order for the construction of the instrument, and requested Professor Ellet to give any suggestions as to the details which might be required.

The advantages of this liquid are: — 1. That it gives off no appreciable vapor at any atmospheric temperature; and 2. That it does not absorb or transmit air. The objections to its use are: — 1. The liability to accident from the corrosive nature of the liquid, either in the filling of the tube or in its subsequent breakage; and, 2. Its affinity for moisture, which tends to produce a change in specific gravity. The filling, however, is a simple process, and attended with but little, if any, risk. The acid can gradually be poured into the tube while in its case, slightly inclined to the horizon. Any accident from breakage can be prevented by properly securing the whole instrument in an outer case, which will also serve to equalize the temperature. To prevent the absorption of moisture, the air may be previously passed through a drying tube apparatus. The only point in which water would be preferable to sulphuric acid is the less specific gravity of the former, and consequently the greater range of its fluctuation, which is as 20 : 11, nearly.

The general appearance of the instrument, and the several contrivances for adjustment and reading, are in accordance with the reputation of the skilful and intelligent artist who made it. The glass tube is two hundred and forty inches long, and three fourths of an inch in diameter, and is enclosed in a cylindrical brass case of the same length, and two and a half inches in diameter. The glass tube is se-

cured in the axis of the brass case by a number of cork collars, placed at intervals; which, while they prevent all lateral displacement of the tube, enable it to be moved upwards and downwards for the adjustment of the zero-point.

The reservoir consists of a cylindrical glass bottle, of four inches in diameter, with two openings at the top; one in the axis to admit the lower end of the long tube, which is tapered to about one half of the general diameter, the other to transmit the varying pressure of the atmosphere.

To adjust the zero-point, the whole glass part of the apparatus, together with the contained acid, is elevated or depressed by a screw, placed under the bottom, until the level of the acid in the reservoir coincides with a fixed mark.

The scale for reading the elevation is divided into inches and tenths, and by means of a vernier, moved by a rack and pinion, the variations can be measured to a hundredth of an inch, and estimated to a still smaller division.

The vernier itself is not immediately attached to the cylindrical brass case, but to a sliding frame, which can be moved along the whole opening through which the entire range of the column is observed. The motion of the frame enables us to make the first rough adjustment, and that of the rack and pinion the minute one.

The drying apparatus, placed between the external air and the interior of the reservoir, consists of a tubulated bottle with two openings containing chloride of calcium, and connected with the reservoir by an India-rubber tube, by which arrangement the air is deprived of its moisture.

To ascertain the temperature of the column of the liquid, two thermometers are attached, one at the top and the other near the bottom.

The whole apparatus is enclosed in an outer glazed case of twelve inches square, which serves, as mentioned before, as well for protection as for equalizing the temperature, which is with sufficient accuracy ascertained by taking the mean of the two thermometers.

A large correction is required in this barometer for the expansion and contraction by the changes of temperature. To determine the amount of this, the specific gravity of a quantity of the acid with which the barometer had been filled was taken at different temperatures. This process was performed with a very sensitive balance, by Dr. Easter, in the laboratory of the Institution.

3. Some Experiments on Visual Direction. By Professor John Brocklesby, of Trinity College, Hartford, Ct.

Some years ago I met with a brief allusion to the existence of an "Essay on Single Vision," published by Dr. Woodhouse in the Philosophical Magazine. In this treatise, it seems, the author endeavors to prove from certain experiments and physiological considerations, that one eye is wholly occupied with vision, while the other is nearly or entirely passive. My attention was arrested by this inference, and as the essay, with its detailed experiments, was not accessible, I was led to make some investigations upon this point, and on others kindred to it. These investigations, and the conclusions to which they lead, are the subject of the present paper. It is well known, that if, while looking at a remote object with both eyes open, we interpose a second at a short distance from us, the latter will appear *double;* the image formed by the right eye being seen towards the left hand, and that formed by the left towards the right hand; the proximity of the images depending upon the magnitude of the interposed body, and its distance from the eyes. As we cannot, at the same time, range both the separate images of the nearest object with the remote one, and yet as a matter of fact we do in some way range objects thus situated, when both eyes are open, it follows that a solution of this point touches on the one in question. In order to ascertain in what manner I was enabled to range objects at different distances by double vision, I instituted the following personal experiments. How far the results obtained are to be regarded as general, will appear in the subsequent pages.

Of the Range of a Point near the Eyes with an Object more or less remote. — If, with both eyes open, I bring before me, beyond the limit of distinct vision, a small point like that of a pencil, and endeavor to range it with some object more or less remote, as a figure on a wall, or the ball of a spire, I find that two images of the point at once appear, but that the image seen by the *right eye* is immediately and involuntarily selected as that which ranges with the remote object. This is proved by the fact, that, if the left eye is closed, the range is still preserved; but if the right eye is closed, and the left remains open, the range is destroyed, the point being seen to the right of the distant object. Moreover, if, reversing the experiment, I first bring the

point and object in a line with the right eye alone, the left being closed, it is found that they continue in a range when both eyes are open, but that if the range is first taken with the left eye only, and the objects are then viewed with both eyes, the range ceases to exist; the point being seen to the left of the remote object. These changes in visual direction are more marked when the point is brought within the limit of distinct vision, and the second object is a few feet distant. Upon taking *two* or more points, instead of one, and ranging them with some object at a distance, the same results occur as in the former case. The optical effect, however, is more striking than when one point is used, and the power of the right eye to control the range is very evident.

Range of a Straight Line. — Since an infinite number of material points, placed one behind the other, so near as to touch, may be regarded as forming a straight line, it might be reasonably inferred that a *straight line* would present the same phenomena in respect to visual direction as a point, or any number of points. Experiment shows this inference to be correct, for, upon ranging a line, as the edge of a rule, with a second object, both eyes being open, the range, upon closing the left eye, is still maintained, but is lost when the right eye alone is closed; the edge in the last case not being seen in the direction of its length, but obliquely. If, also, as before, the range is first taken with the right eye, it is preserved when both eyes are open; but if with the left, it is apparently lost when viewed with both eyes.

Range of a Surface. — If similar experiments to those just detailed are made with a *surface* of small extent, the same prevailing power of the right eye to control the visual direction is still manifested, but is most strikingly exhibited when *several surfaces* are made to range with a fixed object. Thus, if a number of bright objects are taken, as the flames of several candles, the ruling power of the right eye is finely revealed, by first ranging the flames in a line with both eyes, and then beholding them with each eye alone.

Range of a Solid. — By the union of numerous material surfaces, equal each to each, and having their centres in the same straight line, solid cylinders and prisms may be formed, and the same law of visual direction that belongs to these surfaces belongs also to the solids that they compose. For if a small straight *rod* is sighted, in the direction of its length, with a second object, in the various ways that have been

mentioned, the range is the same when it is viewed in succession by the right eye and by both eyes; but different when the left is used instead of the right.

Range of an Opening. — If a ring is taken, or a card with an opening in it, and the card is so held that I look through the opening at some distant object, both eyes being open, the two images of the opening formed by the eyes are readily perceived, but it is only through that which belongs to the right eye that the object is seen; for if the left is closed, the object is still visible through the opening; but if the right is closed and the left is open, it is no longer seen through the orifice. If the range at first is taken with the right eye, there is no shifting of the visible direction of the object when both eyes are employed in vision, the left coming to the aid of the right. But when the range at the outset is taken with the left eye, and the right is then opened, the influence of the left eye upon the range is very feeble, and seems almost destroyed by the power of the right.

If, instead of one perforated card, two or three are employed at the same time, the object being viewed through the cards placed one behind the other, the influence of the right eye is rendered more evident. For when the object is first seen through the several openings with both eyes open, upon closing the right, not only does the object become invisible, but some of the openings also; for instance, I may see through the opening of the first card the unbroken face of the second, the orifice in the latter being out of sight.

Range of a Tube. — A tube may be regarded as composed of a number of *material* rings; it might therefore be expected to present the same visual phenomena as orifices and rings, and such is found to be the case upon looking through a tube at a distant object, in the different ways that have been mentioned.

By directing especial attention to the left eye, it may be made to control the range instead of the right, and objects can be seen by it in the same direction as when viewed by both eyes; but this control ceases with the particular effort of the will that calls the eye to discharge an unusual duty. On the other hand, in the normal condition of vision, when objects are viewed without any special exertion of the will, I find from the experiments detailed, that, on account of habit or otherwise, I invariably neglect the image formed by the left eye and take that belonging to the right; and that the visual direction of *points*, *lines*, *sur-*

faces, and *solids*, *near* to the observer, is always determined by the right eye.

But a question arises, Is this dominant power of the right eye a peculiarity of the individual, like Daltonism, or is it *generally* true? In reply, I would state that I have been accustomed for a length of time to propose some of the preceding experiments to different individuals, and the result has almost invariably been, that, when both eyes are open, the right eye determines the visual direction of near objects. Out of as many as seventy or eighty cases, not more than three or four exceptions from this rule have been detected. In one of these exceptions the right eye was weaker than the left, and the latter discharged the functions of the former in the aforesaid experiments, and *vice versa*. Another exception occurs in the case of a civil engineer, who is accustomed to sight objects with both eyes open, by glancing suddenly from one to the other. In this instance, the observer, when ranging a near object with a distant one, with both eyes open, finds the image of the former to be situated half-way between its two positions as beheld with each eye separately.

In view of these facts, I am inclined to believe that most persons, when they gaze upon a near object with both eyes open, habitually neglect the image formed by the left eye, and employ that of the right to fix the visual direction, — in fact, that we are *right-eyed*. Moreover, that cases sometimes occur where the left eye is used for this purpose, and in such exceptional instances the observers may be termed *left-eyed*.

A boy shoots marbles with both eyes open, and a sportsman not unfrequently brings down his game in the same manner; but I apprehend that in both instances the aim is as truly taken as if one eye was shut, and that either the right eye or the left gives the range, while the other is passive.

If it is true that the right eye, under the circumstances mentioned, possesses a superiority over the other, the fact would be in strict accordance with some other physiological phenomena. We are all aware of the pre-eminence which the right hand has over the left, either from habit or otherwise, — how much more ready and quick it is in all its motions, being the first to advance whenever the hand is needed. So marked is this characteristic, that we term expertness and activity of manipulation *dexterity*. Right-handedness constitutes

the law, left-handedness the exception. The same fact is observed in respect to the feet. In the game of football, for instance, the right foot naturally comes first into play, and is decidedly more active than the other. The superiority of one organ of vision over the other would not, therefore, constitute an anomaly; neither would it be surprising if the same phenomenon should be found to exist in respect to one or more of the other senses.

While making some of the preceding experiments, it occurred to me that there might possibly exist such a sympathy between the eyes and the hands that the right hand acts in unison with the right eye, and the left hand with the left eye; so that a left-handed person would be found to be left-eyed, and a right-handed right-eyed. In order to solve this point I had recourse to one who was a skilful blacksmith, and who used his left hand exclusively in wielding the hammer; but in this case it also happened, as in those of right-handed persons, that the right eye took precedence of the left, and the supposed unison of action did not exist.

Thus far, the visual direction of a *near* with a *distant* object has only been considered; but this point may be examined still further, both in reference to *two remote objects* and to the extent of range when we look through an opening. If a surface of considerable extent, as a board a foot wide or more, is placed at a moderate distance from the observer, for instance sixty or seventy feet, and this surface is projected upon the wall of a building at some distance behind, I find that the space on the building which the board conceals is not, as in the case of a near object, limited by the right eye, but is determined as follows. A line drawn from the *right eye* to the *right-hand edge* of the board and continued to the wall fixes, in the normal state of vision, the *right-hand limit* of the concealed portion of the wall; and a line drawn from the *left eye* to the *left-hand edge* of the board, and produced to the wall, determines also the *left-hand limit* of the hidden surface. For, having first projected the board upon the wall with both eyes, I find that, upon closing the right eye and viewing the board with the left, the right-hand edge shifts to the right, while the left-hand edge is unchanged in position; and that, when the right eye is open and the left closed, the left-hand edge shifts to the left, but the other edge keeps its first place. When therefore both eyes are open, the right controls the visual direction of the right edge of the board, and the left the left edge. This fact is still further proved by first

viewing the objects with each eye, and then with both. The horizontal visual angle, therefore, under which the surface is seen when both eyes are open, is less than that under which it is beheld with one eye, by the amount of the angle formed by drawing lines from each eye to one of the vertical edges.

A different rule appears to obtain in respect to the horizontal extent of view that occurs when we gaze through a large opening, as a window, upon the landscape before us. By experimenting, in the way already mentioned, I find the limit of vision to be thus determined. A line drawn from the *right eye* to the left-hand side of the window, and produced onward, gives the position of the *left-hand boundary* of the landscape; and another line drawn from the *left eye* to the *right-hand side* of the window determines the *right-hand* boundary of vision.

By comparing these results with those immediately preceding, it appears that, when a landscape is observed either through an opening or partially obscured by some intervening object, both eyes are employed in fixing the limits of vision, but in a different way, yet in such a manner that a greater extent is seen with two eyes than with one; in the first case, by increasing the visual angle of the landscape, and in the second, by reducing the visible angle of the obscuring object to a minimum.

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4. Redetermination of the Atomic Weight of Lithium. By Professor J. W. Mallet, of Alabama.

A review was taken of the previous determinations of the atomic weight of this element, from which it appeared that but two experiments deserving of confidence are on record, both of which were made by the same process, viz. the estimation of the sulphuric acid in sulphate of lithia by means of a salt of baryta. The extreme difficulty of removing by washing, from sulphate of baryta, the last traces of the salt of baryta used for precipitation, was pointed out as an objection to this process, the quantity of sulphuric acid apparently obtained being rendered too high, and the equivalent of lithia being therefore brought out less than the true number.

The results of three determinations of the chlorine contained in

chloride of lithium were then given, — the first and second experiments being made by precipitating a weighed quantity of this salt with nitrate of silver, and weighing the chloride of silver produced, — the third experiment consisting in the addition to a weighed quantity of Li Cl, dissolved in water, of the solution in nitric acid of a weighed quantity of pure silver (not sufficient for the complete precipitation of the chlorine), and the cautious addition to the liquid, from a graduated pipette, of a very dilute solution of nitrate of silver of known strength as long as a cloud was produced. The precautions necessary in the preparation of pure chloride of lithium were noticed.

The actual results obtained were, — 7.1885 grm. of Li Cl gave 24.3086 grm. of Ag Cl; 8.5947 grm. of Li Cl gave 29.0621 grm. of Ag Cl; and 3.9942 grm. of Li Cl required for precipitation 10.1702 grm. of Ag.

Hence the atomic weights, —

1st. 86.93
2d. 86.96
3d. 86.78

or, as the mean, 86.89 on the oxygen scale, — a number decidedly higher than that previously adopted for lithium, but believed to be deserving of more confidence from the nature of the process pursued and the large quantity of the salt of lithia employed in the present determination.

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5. Ammonia in the Atmosphere. By Professor E. N. Horsford, of Cambridge.

At the New Haven meeting of the American Association in 1850, I submitted a paper upon the Ammonia in the Atmosphere, the conclusions of which, later research, in the course of the same year, satisfied me were radically erroneous. Before the meeting of 1851 I made a new series of determinations, extending from March 1st, down to June 20th, with every precaution to secure accuracy which I could devise. I felt, however, reluctant to publish the results without being able to show wherein the error of the previous research con-

sisted.* The source of error having since revealed itself, I ask to lay the correction before the Association.

The chief points noticed in the research of 1849 – 50 were the influence of the direction of the wind upon the quantities of ammonia observed in the air, and the large amount of ammonia. Both these supposed facts were based upon an error in the process, which I did not fairly and fully take into account until recently. I had removed the bottles containing ammonia compounds from the room in which the determinations were made, and had taken such other precautionary measures to insure reliable results as I could devise, but one important one escaped me.

To increase the extent of absorbing surface in the flasks employed, I spread over the interior flocculent asbesots. At the conclusion of each determination, the contents of the flasks, including the asbestos, were thrown upon a filter. This filter was washed till the wash-water gave no reaction with nitrate of silver. Meanwhile another portion of asbestos had been introduced into the flasks, and a new determination commenced. The first portion of asbestos, with the hydrochloric acid, which could not be entirely washed out, remained several days exposed to the air, absorbing ammonia from the atmosphere, and this asbestos was in its turn, *without ignition*, returned to the flasks, and of course contributed its ammonia in the form of chloride to the next determination. The paper-filter, too, was not renewed except at considerable intervals, and this, with its sal ammoniac, augmented the amount of error. It will be seen that the amounts of ammonia would be exponents of the temperature, and thus, to a certain extent, in keeping with the direction of the wind, which was one of the striking results in my former paper.

The general method observed in my second series was the same as in the first, and that which has been pursued by all who have made this class of determinations. A known volume of air was conducted through a series of flasks containing hydrochloric acid, by means of an aspirator.

My series consisted of six flasks, with slender necks, and of the shape and capacity of those used for determinations of chloride of sil-

* J. Pierre, the average of whose final determinations corresponds almost precisely with that of my last series, was unable to see wherein the error of his first determinations consisted.

ver. The flask nearest the aspirator contained water only. The tube from this flask to the next in succession dipped below the surface of the diluted hydrochloric acid which the flask contained. The next flask contained a little diluted hydrochloric acid. The next contained acid a little more concentrated; the next, a few drops of highly concentrated acid; and the next, water, under the surface of which passed the tube communicating with the preceding flask.

The aspirator was a cask of about twenty gallons' capacity. Of this description there were three, placed for convenience on little platforms mounted on castors. The water was permitted to flow slowly from a cock into a glass jar, the capacity of which in cubic centimetres to a point in the neck had been accurately ascertained.

Two determinations were usually carried forward simultaneously, in all respects under the same circumstances of arrangement, time, and quantity.

The capacity of the glass jars employed was 4260 cc. for each, and they were filled in all from 50 to 240 times for each determination. That is, the amount of air drawn through the aspirator was from $50 \times 4260 = 213{,}000$ cc. to $240 \times 4260 = 1{,}022{,}400$ cc.

At the conclusion of the process the flasks were carefully rinsed out, the contents poured upon a filter, and the filtrate carried down with a few drops of platinum solution over a water-bath nearly to dryness, the precipitate treated with alcohol, and brought on a weighed filter.

The first determination, on March 1st, gave for the platinum precipitate 0.0530 gr. for 50×4260 cc.

The next two made simultaneously for the same volume of air, on

March 15th, gave 1. = 0.0298 gr.
2. = 0.0584 " } difference 0.0286.

The next two, on

March 30th, gave 3. = 0.0570 "
4. = 0.0594 " } " 0.0024.

The next two, on

April 3d, gave 5. = 0.0764 "
6. = 0.0755 " } " 0.0009.

These great contrasts pointed to the necessity of observing many particulars in the mode of determination which in common quantitative analysis are usually dispensed with. The sources of error were various.

The quantity of distilled water employed in rinsing out the apparatus had not been invariably and precisely the same. The hydrochloric acid and bichloride of platinum had not been rigidly the same in quantity, and the amount of ammonia present in them, though once before ascertained, and found to be quite insignificant, was again determined, and found to be very considerable.

600 cc. of distilled water, and 20 cc. of hydrochloric acid, being *about* the quantity employed, and the usual quantity of platinum solution, were evaporated over a water-bath, and gave a precipitate of 0.0699 gr., which at once showed the preceding determinations to be of no value.

The following precautions and modifications were then adopted.

1st. The distilled water employed was prepared by slowly distilling from water to which sulphuric acid had been added.

2d. The hydrochloric acid was prepared in the usual manner, employing the above distilled water.

3d. The filters, hitherto dried in the common steam-chamber for an invariable length of time, were now dried in a Rammelsberg's desiccator for two hours, at a temperature not exceeding 100° C., and then for one half-hour at 120° C.

4th. The filter was dried and weighed in an arrangement of glass tubes, one sliding within the other, open while drying, and reversed and closed while weighing, so as effectually to prevent the absorption of moisture after the filter is once properly dried.

It was ascertained that the filter and the contents so confined did not vary in weight the amount of half a milligramme in three days.

It was also ascertained by two determinations that the weighed filter, after washing with alcohol, and subsequent drying, as above described, did not change its weight in the least.

When, after such drying, the weight had been determined, and after a heat at 120° for another half-hour had not changed it, in the amount of one tenth of a milligramme, it was considered dry.

5th. The quantity of water employed for washing out the flasks was accurately measured out, 600 cc. for each time.

6th. The evaporation was conducted under a sheet of filter-paper, to exclude dust. The last portions were evaporated at a temperature considerably below that of boiling water, as experience had shown that, without this precaution, some of the precipitate adhered to the sides of the evaporating-dish.

When the total residue consisted of only a few drops, alcohol was added.

7th. At the same time, and observing all the same precautions, a corresponding quantity of water, and the exact quantities of hydrochloric acid and platinum solution were evaporated down, and the precipitate (which still amounted to an appreciable quantity) determined and subtracted from the other.

8th. As the quantity of ammonia found proved to be much smaller than it had before seemed, it was decided, instead of fifty gallons of air, as heretofore, to run through the apparatus a much larger quantity. The water from the aspirator was run in the slenderest stream, considerably slower than before.*

With these precautions, determinations were commenced anew at a point uninfluenced by exhalation from any quarter.

1. The two determinations made side by side at the same time, with only 50×4260 cc., gave respectively of platinum precipitate,

April 25th, 1. 0.00180 gr. } difference 0.00055, average 0.002075.
2. 0.00235 " }

The distilled water and reagents evaporated gave a visible trace of platinum precipitate; the weight of the filter with the precipitate after drying was, however, found smaller than that of the filter alone, by the amount of 0.0012 gr., owing to the thermometer having once risen above 120° C. Estimating the precipitate at one fourth of a milligramme by comparing it with subsequent determinations, and subtracting the weight from the above, 0.002075, gives 0.001825 as the average quantity for 1 and 2. This, for the sake of comparison, referred to 100 jars of water $= 100 \times 4260$, gives 0.00365 gr. platinum precipitate.

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* The following precautions may be serviceable to any who may care to repeat the determinations: —

1st. The paper used for filtering the acid rinsings should be renewed for each determination, as the acid, which it is quite impossible to remove entirely from the paper, absorbs ammonia from the air.

2d. The tubes employed for measuring the hydrochloric acid and platinum solution should be rinsed immediately after use.

3d. The filter tubes when taken from the drying-chamber should be left a quarter of an hour to cool before weighing.

4th. As the platinum precipitate is not absolutely insoluble in alcohol, the quantities employed should be measured, and the alcohol should be rectified.

2d Determination, March 1st, 100 × 4260 cc. of air gave of platinum precipitate,

3. 0.00290 gr.
4. 0.00255 " } difference 0.00035, average 0.00272 gr.

The precipitate from the water and reagents was a mere trace.

3d Determination, May 18th, 100 × 4260 cc. of air gave of platinum precipitate,

5. 0.0078 gr.
6. 0.0072 " } difference 0.0006, average 0.0075.

The precipitate from the water and reagents was 0.0010 gr., which subtracted from 0.0075 gr. gives the average of 5 and 6,

0.0065 gr.

4th Determination, May 28th, to June 5th,

240 × 4260 cc. = 1.022400 cc. gave of platinum precipitate,

0.00645 gr.

The precipitate from the water and reagents amounted to 0.0007 gr., which, deducted from the above, gives 0.00575, which, for 100 jars = 0.00239 gr.

The next and last determination was made on the summit of Prospect Hill, in the neighborhood of Cambridge, distant from dwellings and habitations of every kind, and about 150 feet above tide level.

5th Determination, June 18th and 20th, 180 × 4260 cc. of air gave of platinum precipitate

0.00705 gr.

The water and reagents gave 0.00140 gr., which, deducted from the above, leaves 0.00565 gr., which, calculated for 100 × 4260, gives 0.00314 gr.

These results placed together are as follows: —

		426,000 cc. of air gave $PtCl_2NH_4Cl$	$= NH_3$	= in 1,000,000 cc. tr.
April 25th,	1. 2.	0.00365 gr.	0.000278 gr.	0.0006158 gr.
May 1st,	3. 4.	0.00272 "	0.000207 "	0.0004592 "
May 18th,	5. 6.	0.00650 "	0.000495 "	0.0011619 "
May 28th,	7.	0.00239 "	0.000182 "	0.0004037 "
June 18, 20,	8.	0.00314 "	0.000240 "	0.0005633 "
			Average =	0.0006407 "

This is about one half-millionth of the average weight of the air. This average is very nearly coincident with the result of the last series of observations by J. Pierre,* which were continued through nine months with 4075 litres of air. One cubic metre of air contained 0.00065 gr.

His first series,† which he afterward discovered to be faulty, gave for one cubic metre 0.0045 gr., or about three and a half millionths of the weight of the air.

Fresenius‡ found in the atmosphere of daylight for forty days in August and September, 1848, for one million parts of air by weight, only 0.098 parts, and for night air for the same weight, 0.169 parts.

Kemp§ found for the same 3.40, and Grager‖ 0.333. Ville¶ made sixteen determinations in 1849–1850, employing from 20,000 to 55,000 litres of air. His range was from 17.76 gr. to 31.71 gr., averaging 23.73 gr. for one million kilogrammes of air.

A second series by the same observer in 1850 (1851?) gave for the same weight of air from 16.52 gr. to 27.26 gr., average 21.10 gr. For the average of the two, 22.41 gr., or in one million parts by weight, 0.02241 parts of ammonia.

Bineau** estimates the air about Lyons to contain from one fourth to one fifth of one millionth of its weight of ammonia. That of Caluire to contain in winter forty billionths, in summer eighty billionths.

Bineau's†† observations are based upon the supposition that the ammonia and carbonic acid of the air are in equivalent proportions, and that both were alike absorbed by his method.

He obtained by his method for Lyons, in 1,000,000,000 parts, from

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* Liebig and Kopps, Jahresbericht, 1853, p. 333.

† Liebig and Kopps, Jahresbericht, 1852, p. 356.

‡ Liebig and Kopps, Jahresbericht, 1849, p. 258.

§ Pharm. Centr. Blatt, 1848, p. 315.

‖ Liebig and Kopps, Jahresbericht, 1849, p. 258.

¶ Liebig and Kopps, Jahresbericht, 1852, p. 356.

** Liebig and Kopps, Jahresbericht, 1854, p. 315.

†† My own determinations in 1849 were so exceedingly erroneous as not to be entitled to record, but may show how wide a departure from a true result may be possible where a method is defective. One million parts by weight gave from 1.2 to 47.6 parts of ammonia, the average of which is nearly fifty times as great as was found to be present.

200 to 250 parts of ammonia, and at Caluire, in winter 40, and in summer 80 parts.

Placing these results in form for comparison, they give in one million cubic metres, according to

Grager,		432.00 gr.
Kemp,		4423.00 "
Fresenius,	day,	127.27 "
	night,	219.47 "
Ville, 1st series,		30.81 "
" 2d series,		27.39 "
Bineau,	Lyons average,	292.50 "
	Caluire, winter,	52.00 "
	Caluire, summer,	104.00 "
J. Pierre, 1st series, (erroneous,)		4500.00 "
" 2d series,		650.00 "
Horsford,		640.70 "

This near coincidence of the last two results, taken in connection with the time consumed in producing the first, and the number and differential character of the determinations giving the second, entitles them, possibly, to a higher degree of confidence than any of the preceding results.

Taking the round number, 645, as the number of grammes in one million cubic metres of air, or 1,298,701 kilogrammes of air, and taking, according to Marchand, the weight of the atmosphere at 5,263,623,000,000,000,000 kilogrammes, and assuming it to be of uniform constitution, we have in the total atmosphere 2,614,178,964,211 kilogrammes of ammonia.* Or, expressed in English weights, 11,613,808,176,000,000,000,000 pounds of atmospheric air contain 5,767,999,157,462 pounds of ammonia.

* In Fresenius's estimates, as published in Erdmann and Marchand's Journal f. Prakt. Chemie, Vol. XLVI. pp. 101–106, I find two errors that have escaped the author's eye. He gives Kemp's quantity of ammonia in 1,000,000 parts of air by weight at 3.68. It should be 3.40. He finds the number of kilogrammes of ammonia in the air, upon the average of 0.133 parts in 1,000,000 by weight (his own determination), and Marchand's estimate as given above, to be 4,079,042 kilogrammes. It should be 700,061,859,000 kilogrammes.

IV. PHYSICS OF THE GLOBE.

1. Approximate Cotidal Lines of Diurnal and Semi-Diurnal Tides of the Coast of the United States on the Gulf of Mexico. By A. D. Bache, Superintendent U. S. Coast Survey. [Communicated by Authority of the Treasury Department.]

At successive meetings of the American Association I have presented approximate cotidal lines for the Atlantic and Pacific coasts of the United States, drawn from the tidal observations of the Coast Survey. I now present similar lines for our coast on the Gulf of Mexico.

The problem is a very different one from either of the others referred to. The tides on the Atlantic coast are of the regular semi-diurnal class, and easily discussed by the forms already elaborately prepared by Lubbock and Whewell. The diurnal inequality is not large; indeed, though easily recognized at particular periods, and then quite characteristic, in general it is difficult to trace, and often irregular in magnitude, and even in sign. Those of the Pacific coast are remarkably regular in the semi-diurnal and diurnal waves, and both rise to such heights as to make observation easy. On the Gulf coast, on the contrary, the tides are small, and therefore easily affected by extraneous circumstances, and, as a rule, on more than two thirds of the coast the semi-diurnal tides are very small, and in fact are masked by the diurnal tide. The comparatively imperfect discussion which has been made of these tides requires many steps in the discussion to be supplied, and sometimes leaves us in doubt as to the exact interpretation of the results.

By way of preparing for the present discussion, and to avoid running into too great length at this time, I gave at the last meeting of the Association an account of the tidal observations made on our Gulf coast, and showed the type curves for the different stations from Cape Florida to the Rio Grande.* I also explained the method of decomposition of the curves of observation into diurnal and semi-diurnal waves, and gave the analysis of the type curves at the several tidal stations. From Cape Florida, along the Keys, and up the western coast of the

* Proceedings of the American Association for the Advancement of Science, Providence Meeting, 1855, p. 152.

peninsula, to St. George's, the tides are of the half-day class, with a large diurnal inequality; from St. George's, which belongs to the day class, to Southwest Pass, they are of the day type, the semi-diurnal tide almost disappearing; at Dernière Island, Calcasieu, and Galveston they resume as a rule the half-day type, and lose it almost completely at Aransas and the mouth of the Rio Grande. Isle Dernière, and less distinctly Calcasieu, show cases of interference in the semi-diurnal wave, two high waters being at times easily traced in the semi-diurnal curve.

The character of the tidal phenomena themselves, the peculiarities in configuration and in depth of the basin, the limited extent over which our researches spread, and various other circumstances, contribute to render this work less satisfactory than the former. Some of these will, in the end, disappear, as the Gulf is more fully explored in the progress of the survey. Our information thus far extends to but one entrance of the basin, that by the Gulf of Florida, and of this to but one shore, while of the nature of the tide wave which enters from the Caribbean Sea, through the straits between the western end of Cuba and the eastern end of Yucatan, we have no reliable information. Some of these causes render present speculation premature, and lie at the very threshold of attempts to trace out the great interference problems which present themselves.

The progress of this discussion has also shown that observations of longer period are necessary in many cases to give data for conclusive results. This of itself is a great point gained, and the practical results for the charts of this coast have repaid all the labor which has been expended on the observations. Navigators were absolutely without information other than the most vague in regard to the tides of the Gulf.

The hourly observations at each station being plotted in diagrams upon a suitable scale, the curves of observation were decomposed, by the graphical method introduced by Mr. Pourtales, into a diurnal and semi-diurnal curve. It may be proper to observe here, that several comparisons have been made between this method and that which I had formerly used by the sine curves, and with generally coincident results. The graphical method, besides being less laborious, is free from the hypothesis of the sine curve. These decompositions were made chiefly by Messrs. Fendall and Heaton of the tidal party, and occasionally by Professor Pendleton and Mr. S. Walker.

That the diurnal wave is the principal feature in these tides, will appear from the annexed table, which gives the names and positions

TABLE I.

Stations.	Height of Semi-diurnal Tides.	Height of Diurnal Tides.	Height of Observed Tides.
	ft.	ft.	ft.
Cape Florida,	1.6	0.2	1.5
Indian Key,	1.9	0.6	1.8
Key West,	1.2	0.7	1.4
Tortugas,	1 0	1.0	1.2
Egmont Keys,	1.1	1.6	1.4
Cedar Keys,	2.4	1.5	2.5
St. Mark's,	2.2	1.8	2.2
St. George's Island,	0.2	1.6	1.1
Pensacola,	0.2	1.1	1.0
Fort Morgan (Mobile Bay),	0.2	1.1	1.0
Cat Island,	0.3	1.2	1.3
Southwest Pass,	0.2	1.2	1.1
Dernière Isle,	0.4	1.6	1.4
Calcasieu,	1.3	1.5	1.1
Galveston,	0.5	1.1	1.1
Aransas,	0.5	1.3	1.1
Brazos Santiago,	0.3	0.8	0.9

TABLE II.

Tide Tables in the Gulf of Mexico, the Results of which are Discussed in this Paper.

No.	Stations.	Date of Observation.	Kind of Gauge.	Observers.
1	Cape Florida, Fla.	April 22 to Oct. 31, 1854,	S.R.*	L. E. Tansill.
2	Indian Key, "	Jan. 21 to April 16, 1855,	S.R.	L. E. Tansill.
3	Key West, "	Apr. 20, 1850, to Dec. 31, '51,	Box,	W. Lane & G. W. Goss.
4	Tortugas, "	April 1 to June 22, 1855,	S.R.	C. T. Thompson and F. Buxton.
5	Egmont Key, "	April 22 to Aug. 23, 1854,	"	C. T. Thompson.
6	Cedar Keys, "	Jan. 10 to Mar. 16, 1852,	Box,	G. Wurdemann.
7	St. Mark's, "	Nov. 3, 1854, to Mar. 2, '55,	S.R.	C. T. Thompson.
8	St. George's Isl., "	April 11 to Aug. 16, 1852,	Box,	G. Wurdemann.
9	Pensacola, "	Aug. 27 to Oct. 31, 1852,	"	G. Wurdemann.
10	Fort Morgan, Ala.	Aug. 20, 1850, to May 26, '51,	"	G. Wurdemann.
11	Cat Island, La.	Dec. 29, 1847, to Feb. 13, '49,	"	G. Wurdemann and R. T. Bassett.
12	Southwest Pass, "	Nov. 19, 1852, to Mar. 28, '53,	"	G. Wurdemann.
13	Dernière Isl., "	April 5 to June 12, 1853,	"	G. Wurdemann.
14	Calcasieu, "	Feb. 24 to May 26, 1854,	S.R.	G. Wurdemann.
15	Bolivar Pt., Tex.	Oct. 1, 1853, to June 1, 1854,	"	L. E. Tansill.
16	Galveston, "	Mar. 21, 1851, to Jan. 1, 1853,	Staff,	G. Price and F. Muhr.
17	Aransas Pass, "	Nov. 1, 1853, to Jan. 31, 1854,	Box,	G. Wurdemann.
18	Brazos Sant., "	July 7 to Oct. 13, 1853,	"	G. Wurdemann.

* Self-registering tide-gauge.

of the tidal stations, the average rise and fall of the tide at each, and the height of the diurnal and semi-diurnal waves composing the observed tide. Table No. II. shows the periods during which the tidal observations were made, and the names of the observers.

A diagram (No. 1) shows these results graphically. A curved line corresponding to the general outline of the shore, cutting off its irregularities, is drawn on the chart of the Gulf coast, and then developed into a straight line. Thus the tidal stations are plotted at their distances from each other measured along the general line of the coast. For use by navigators, any intermediate stations may be marked in, in the same way, and a rough approximation to the character of the tide be obtained by the interpolation.

The least observed height is 0.9 foot, at Brazos Santiago, and the greatest 2.5 feet, at Cedar Keys. The least height of the average semi-diurnal tide is 0.2 foot, at Southwest Pass, and the greatest 2.4 feet, at Cedar Keys. The least height of the average diurnal tide is 0.2 foot, at Cape Florida, and the greatest 1.8 feet, at St. Mark's. Of course, these numbers are, for reasons easily seen, only approximations.

As we enter the Gulf of Mexico by the Straits of Florida, the height of the tide first increases, then decreases. Passing into the bight at the upper end of the Florida peninsula, the rise is greatest; west of St. George's it diminishes, to rise again in the bight formed by the southern coast of Louisiana and the eastern coast of Texas.

In the decompositions here traced, and in the very laborious discussions, tentative and final, of the whole of the observations upon which this paper is based, I would acknowledge the great assistance derived from the labors of Assistant L. F. Pourtales, in charge of the tidal division of the Coast Survey. The unwearied assiduity of his own labors, and his intelligent supervision of the work of others, have been felt at every step in the progress of these investigations. They have required, on his part, great resources of ingenuity, patience, and knowledge.

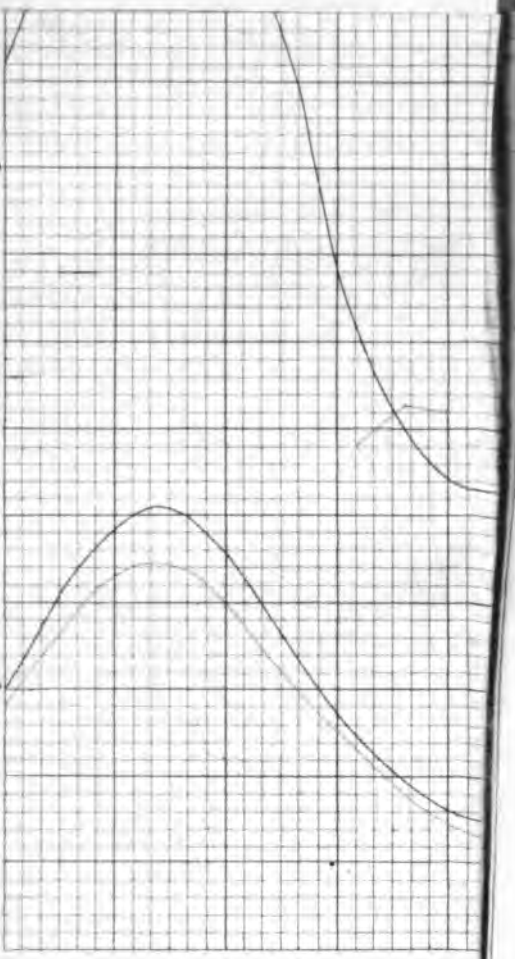
In discussing semi-diurnal tides, the luni-tidal interval of high or low water, varying only from a certain mean within moderate limits, affords a cardinal datum (the establishment) for the times. In the diurnal tides this datum is wanting.

The law of the change of the diurnal tide, as expressed in the formula of Professor Airy (Tides and Waves, Encyclopædia Metropoli-

DIAG

Showing the variations in the luni[tidal] a[ttraction]

16 Moon's declination at Eg[reenwich]



tana, p. 254, Art. 46), is in general represented; but the great flatness in the form of the curves at particular relations of the moon's right ascension and declination, required by the formula, does not occur. The general form of these curves is shown upon the diagram No. 2, where the abscissæ represent the days, and the ordinates the luni-tidal intervals of high water. About the maximum of declination, for some four to six days, the luni-tidal intervals are moderately constant, and the average of these is what I have taken for a comparison of the luni-tidal intervals to trace the progress of the diurnal wave. The variations from day to day being less than the probable irregularities in the times of high water and the uncertainties in the observations, these means give suitable numbers for comparison. The result would not have been greatly different had only a few of the observations at either end of the declination period been thrown off; but after examination we found these numbers to present apparently the best results.

At four of the stations, namely, Key West, Fort Morgan, Cat Island, and Galveston, hourly observations were continued during a year and upwards, and the decompositions in all the cases but Cat Island embrace that period. The annual change of diurnal establishment (using this term as a convenient one in the sense heretofore stated) is very clearly seen in all these cases, and is shown in diagram No. 3. The law of the change is beautifully developed in the larger tides of the Western coast, and, as deduced from the San Francisco observations, is shown upon the same diagram. In all the cases the actual computed results for the different half-monthly periods are shown by the broken lines on the diagrams, and the curve, representing the law, is drawn with a free hand among the points. The general resemblance of these curves, with however different maximum ordinates, is very striking, showing that the law of the change is the same, only the coefficients of the functions varying.

On diagram No. 4 the curve derived from Professor Airy's formula (Theory of Tides and Waves, Encyclopædia Metropolitana, p. 254, Art. 46) is drawn, as well as that from observation for San Francisco, and the general conformity is quite striking. In making use of the curves as expressing the law of annual change, one of the branches has been turned over upon the other, so as to use the mean of the two periods of six months.

At the other fourteen stations on the Gulf of Mexico, the observations were continued from one to three lunations, and fell in different parts of the year. To reduce these, therefore, to the same period of the year, it is necessary to employ the data from the localities where the whole annual change was embraced. The results are plotted on diagram No. 4; those from the Brazos to Southwest Pass on the curve for Galveston, those from the Southwest Pass to St. George's on the curve for Fort Morgan, and those from St. George's to Cape Florida on the curve for Key West. There is, except in one case, a general conformity in the observed changes, and in those deduced from the other comparisons; at least, there are no greater contradictions than those presented by the observations from which the mean curves are drawn. From these plottings, the correction necessary to reduce the results to the mean of the year are derived, and the annexed table shows the diurnal interval as deduced directly from the observations and as corrected. It is satisfactory to see that the correction makes the results more conformable to law, increasing therefore the probability that the correction is rightly applied, and is approximately correct in magnitude.

TABLE III.

No.	Stations.	Latitude.	Longitude.	Longitude in Time.	Mean Diurnal Lunitidal Interval near Maximum of Moon's Declin.	Longitude + Establishment.	Correction for Transit.	Correction for Depth.	Correction for Yearly Variation of Diurnal Lunitidal Interval.	Corrected Cotidal Hour.
		° ′	° ′	h. m.	h. m.	h. m.	h. m.	h. m.	h. m	h. m.
1	Cape Florida,	25 40	80 9	5 21	14 27	19 48	0 27	0 20	+ 0 18	19 19
2	Indian Key,	24 52	80 44	5 23	17 0	22 23	34	20	— 42	20 47
3	Key West,	24 27	81 53	5 28	18 32	24 0	37	19	0	23 4
4	Tortugas,	24 34	82 59	5 32	18 5	23 37	36	10	+ 43	23 34
5	Egmont Key,	27 36	82 46	5 31	19 19	24 50	39	20	+ 1	23 52
6	Cedar Keys,	28 58	82 57	5 32	22 27	27 59	43	45	— 57	25 34
7	St. Mark's,	30 0	84 11	5 37	21 56	27 33	42	22	+ 20	26 49
8	St. George's Island,	29 35	85 12	5 41	19 41	25 22	42	25	+ 37	24 52
9	Pensacola,	30 18	87 15	5 49	21 28	27 17	42	17	+ 22	26 40
10	Fort Morgan,	30 9	88 0	5 52	21 21	27 13	42	14	0	26 14
11	Cat Island,	30 6	88 38	5 55	22 21	28 16	43	1 21	— 11	26 1
12	Southwest Pass,	28 56	89 22	5 57	19 28	25 25	39	21	+ 59	25 24
13	Dernière Island,	28 58	90 58	6 4	19 19	25 23	38	24	+ 1 37	25 58
14	Calcasieu,	29 40	93 21	6 13	19 22	25 35	39	17	+ 1 27	26 6
15	Bolivar Point,	29 23	94 46	6 19	21 40	27 59	43	12	+ 1 24	28 28
16	Galveston,	29 18	94 41	6 19	22 29	28 48	43	30	0	27 35
17	Aransas Pass,	28 15	96 31	6 26	19 46	26 12	40	17	+ 0 43	26 0
18	Brazos Santiago,	26 6	97 10	6 29	20 45	27 14	41	15	— 0 56	25 22

The first column of the table contains a number for reference; the second, the name of the tidal station; the third, fourth, and fifth, the latitude and longitude, the latter in degrees and in time; the sixth, the luni-tidal interval about the maximum of declination; the seventh, the sum of this last-named number and the longitude in time; the eighth, the correction to reduce the observations to the same transit; the ninth, the correction for depth, carrying these by the law of depth to deep water; the tenth, the correction to reduce the observed luni-tidal interval at maximum to the mean of the year; the eleventh, the corrected cotidal hour.

The table enables us satisfactorily to trace the diurnal wave from Cape Florida to the Tortugas, across by the deep water of the Gulf to Southwest Pass, at the entrance of the Mississippi, and from this line of deep water to the western coast of the peninsula of Florida, by Egmont Key (Tampa), Cedar Keys, St. Mark's, and St. George's Island, and in the bay between Southwest Pass and St. George's, by Cat Island, Fort Morgan, and Pensacola. Again, in the bight between Southwest Pass and the Rio Grande, to the Rio Grande, Isle Dernière, Aransas, and Calcasieu, up to Galveston.

In obtaining the general direction of the cotidal lines, I have followed the method of grouping used in my former papers in the forms given by Professor Lloyd. It is easy to obtain an idea of the movement of the diurnal wave in this way, but the selection of the groups required a tedious set of trials, and the discussion of many groups which appeared natural proved very unsatisfactory. The burden of the computations for this work has fallen upon Mr. John Downes.

Table No. IV. shows the groups selected, with a letter attached for reference, the names of the stations constituting the groups, the mean latitude and longitude and cotidal hour of the group, the values of the coefficients of each, the angle of the cotidal line with the meridian, the difference of the cotidal hour for one mile perpendicular to the movement of the wave, and the velocity in miles per hour.

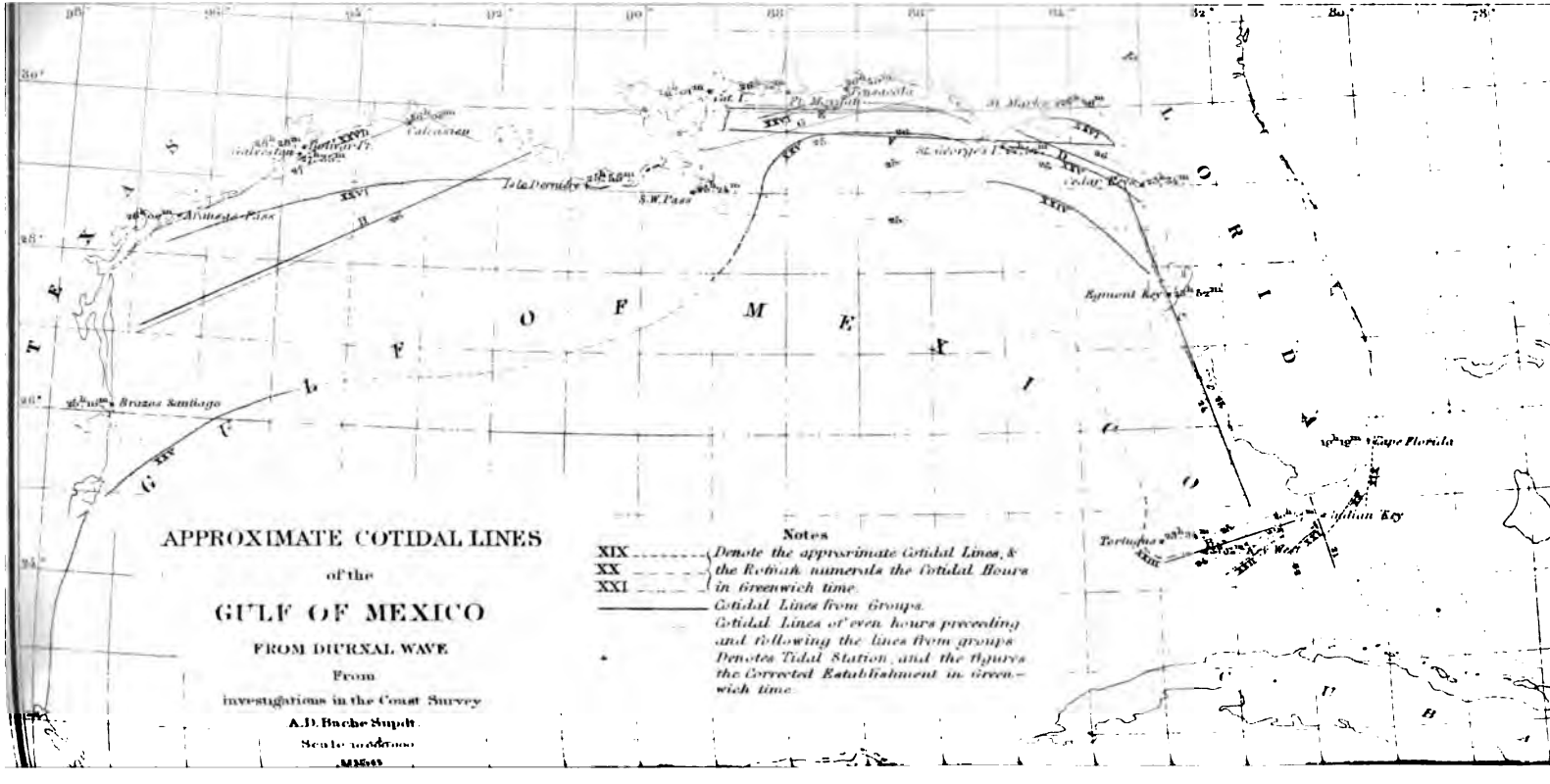
On the character of these groups I would remark as follows: — Group A, Cape Florida, Indian Key, and Key West, and B, Indian Key, Key West, and Tortugas, give a natural movement for the wave, though showing a more abrupt change than is probably real. The computed and observed cotidal hours differ, at the greatest, but one minute and a quarter. The next group, C, gives a satisfactory idea

TABLE IV.

Discussion of Groups of Tidal Stations for Diurnal Wave.

	Stations.	Mean Longitude.	Mean Latitude.	Mean Cotidal Hour.	M Diff. of Cotidal Hour for one Geog. Mile of Longitude.	N Diff. of Cotidal Hour for one Geog. Mile of Latitude.	Angle $[\text{tang} = \frac{N}{M}]$ Cotidal Angle.	$\sqrt{M^2+N^2}$ Diff. of Cotidal Hour corresponding to one Geographical Mile Perpendicular to Cotidal Line.	Miles per Hour of Tidal Wave.
A	Cape Florida, Indian Key, Key West,	° ′ 80 55	° ′ 25 0	h. m. 21 · 3	—1.978	—0.509	° ′ —14 28	2.052	29.2
B	Indian Key, Key West, Tortugas,	81 52	24 38	22 28	—0.890	—3.240	74 38	3.360	17.8
C	Key West, Egmont Key, Cedar Keys,	82 32	27 0	24 10	5.251	1.695	—17 53	5.518	10.9
D	Cedar Keys, St. Mark's, St. George's Island, ...	84 7	29 31	25 45	1.095	2.358	—65 5	2.600	22.7
E	St. George's Island, Pensacola, Fort Morgan, . . .	86 49	30 1	25 55	0.055	2.645	—88 49	2.645	22.7
F	Cedar Keys, St. Mark's, St. George's Isl., Pensacola, Fort Morgan, Cat Isl., S. W. Pass, . .	86 31	29 43	25 56	0.048	0.911	—86 58	0.910	66.0
G	St. George's Island, Pensacola, Ft. Morgan, Cat Island, S. W. Pass, . .	87 41	29 49	25 50	—0.275	1.092	75 52	1.127	53.1
H	S. W. Pass, Dernière Isl., Calcasieu, Galveston, Aransas, Brazos, . . .	93 45	28 28	26 4	—0.241	0.944	63 19	0.974	61.6

of the movement of the wave passing round the Tortugas and up along the coast of the peninsula, over the extensive flat which borders it. The next group, D, Cedar Keys, St. Mark's, and St. George's, presents a perfect agreement between the computed and observed cotidal hours, and a direction and velocity agreeing with what might have been supposed. The same is true for group E, St. George's, Pensacola, and Fort Morgan. The more general group, F, including the stations from Cedar Keys to Southwest Pass, agrees in its indica-


APPROXIMATE COTIDAL LINES
of the
GULF OF MEXICO
FROM DIURNAL WAVE
From
investigations in the Coast Survey
A.D. Bache Supdt.
Scale 1:2,000,000
M 2599
Notes
XIX
XX
XXI
Denote the approximate Cotidal Lines, & the Roman numerals the Cotidal Hours in Greenwich time.
Cotidal Lines from Groups.
Cotidal Lines of even hours preceding and following the lines from groups.
Denotes Tidal Station, and the figures the Corrected Establishment in Greenwich time.
Brazos Santiago
Mustang Pass
La Dernière
S.W. Pass
Calcasieu
Cat I.
Pt. Mazolah
Pensacola
St. Georges I.
Cedar Keys
Egmont Key
Cape Florida
Indian Key
Tortugas
Key West
TEXAS
LOUISIANA
FLORIDA
GULF OF MEXICO

tions with those given by the partial groups ; as does also G, including the stations from St. George's to Southwest Pass. In passing westward and southward, the direction of the line changes rapidly, and no satisfactory adjustment by groups could here be made. From Southwest Pass to the Brazos Santiago, the smaller groups gave decidedly anomalous results for adjacent stations, pointing to the more general arrangement of the lines shown by group H, composed of Southwest Pass, Dernière Isle, Calcasieu, Galveston, Aransas, and Brazos Santiago. The agreement of the cotidal hours, as computed and observed, is only tolerable. The results of the computations for Southwest Pass, Dernière Isle, and Aransas differ severally but 10, 1, and 9 minutes from the observed, but those for Calcasieu, Galveston, and Brazos differ 60, 33, and 44 minutes.

On the map No. V. a rough outline of the Gulf coast is traced, and the cotidal hours are marked near the stations. The mean cotidal line for each group, and the hour before and after the mean hour, are marked on the map, showing the direction and velocity of the diurnal wave as given by the groups. From a consideration of these, and of their necessary connection, the cotidal lines are approximately drawn. The main cotidal line of the northern shore of the Gulf, as traced upon the chart, is that of twenty-six hours; twenty-seven occurring at the head of the bight in which Galveston lies. The twenty-five hour line appears at Cedar Keys and touches the coast again below Brazos, twenty-three is at the Tortugas and Key West, and nineteen at Cape Florida.

Semi-Diurnal Tides.

The Table No. V. of semi-diurnal tides is in the same form as No. III. for diurnal tides. It contains a number for reference, the name of the station, its latitude, the longitude in arc and in time, the establishment, the same in Greenwich time, the correction for transit and for depth, and the corrected cotidal hour.

In tracing the semi-diurnal wave as it enters the Straits of Florida, we find, after a slight contradiction between Cape Florida and Indian Key, a general increase of the cotidal wave in the right direction to the Tortugas. The semi-diurnal wave here gives the difference of time between Cape Florida and the Tortugas of but $1^{h.}\ 24^{m.}$, while the diurnal wave gives $4^{h.}\ 15^{m.}$. The lagging of the diurnal wave, which

at Cape Florida is $1^{h.}\ 44^{m.}$, at Indian Key is $3^{h.}\ 22^{m.}$, at Key West $4^{h.}\ 31^{m.}$, and at the Tortugas $4^{h.}\ 23^{m.}$.

The semi-diurnal wave passes across the Gulf to the Southwest Pass as did the diurnal, the establishment at the Tortugas being $14^{h.}\ 25^{m.}$, and at the Southwest Pass $15^{h.}\ 38^{m.}$. The time of crossing by the semi-diurnal wave is, however, $1^{h.}\ 13^{m.}$, while by the diurnal wave it was $1^{h.}\ 50^{m.}$. The lagging of the diurnal wave behind the semi-diurnal, which at the Tortugas was $9^{h.}\ 26^{m.}$, at the Southwest Pass is $4^{h.}\ 49^{m.}$. The mean depth of the portion of the Gulf traversed by the wave computed from the semi-diurnal wave is sixteen hundred and sixty-six fathoms, and from the diurnal six hundred and sixty-six fathoms; for the mean result of the two, one thousand fathoms. The average depth has not yet been ascertained, but probably does not exceed one thousand fathoms.

TABLE V.

Half-Daily Cotidal Hours in the Gulf of Mexico.

No.	Names of Stations.	Latitude.	Longitude		Establishment of Half-daily Tides.	Establishment Greenwich Mean Time.	Correction		Corrected Cotidal Hour.
			In Arc.	In Time.			For Transit.	For Depth.	
		° ′	° ′	h. m.	h. m.	h. m.	m.	m.	h. m.
1	Cape Florida,	25 40	80 9	5 21	8 17	13 38	— 17	— 20	13 1
2	Indian Key,	24 52	80 44	5 23	8 2	13 25	— 16	— 15	12 54
3	Key West,	24 27	81 53	5 28	9 10	14 38	— 18	— 19	14 1
4	Tortugas,	24 34	82 59	5 32	9 22	14 54	— 19	— 10	14 25
5	Egmont Key,	27 36	82 46	5 31	11 26	16 57	— 23	— 20	16 14
6	Cedar Keys,	28 58	82 57	5 32	13 9	18 41	— 26	— 45	17 30
7	St. Mark's,	30 0	84 11	5 37	13 37	19 14	— 27	— 22	18 25
8	St. George's Island,	29 35	85 12	5 41	14 59	20 40	— 30	— 25	19 45
9	Pensacola,	30 18	87 15	5 49	10 53	16 42	— 22	— 17	16 3
10	Fort Morgan,	30 9	88 0	5 52	11 9	17 1	— 22	— 14	16 25
11	Cat Island,	30 6	88 38	5 55	12 53	18 48	— 26	— 81	17 1
12	Southwest Pass,	28 56	89 22	5 57	10 23	16 20	— 21	— 21	15 38
13	Dernière Island,	28 58	90 58	6 4	13 37	19 41	— 27	— 24	18 50
14	Calcasieu,	29 40	93 21	6 13	14 56	21 9	— 30	— 17	20 22
15	Bolivar Point,	29 23	94 46	6 19	16 47	23 6	— 34	— 12	22 20
16	Galveston,	29 18	94 41	6 19				— 30	
17	Aransas Pass,	28 15	96 31	6 26	14 30	20 56	— 29	— 17	19 10
18	Brazos Santiago,	26 6	97 10	6 29	14 45	21 14	— 29	— 15	20 30

From this line of deep water the semi-diurnal wave reaches the stations on the western coast of the Florida peninsula in their order, from south to north, and west. The movement west of St. George's appears to be in the order of Pensacola, Fort Morgan, and Cat Island, while for the diurnal wave it was Cat Island, Fort Morgan, and Pensa-

cola. To the westward of Southwest Pass there is a sudden increase of establishment, as if another semi-diurnal wave brought the tides there. The mean cotidal hour of the five stations west of Southwest Pass is $20^h\cdot 14^m\cdot$, while that of Southwest Pass and three east of it is $16^h\cdot 17^m\cdot$, a difference of about four hours. This, taken with the remarks already made in regard to the appearance of two high waters in the curves for Isle Dernière and Calcasieu, indicates a system of interferences yet to be unravelled.

As was the case with the diurnal wave, the stations at Isle Dernière and Calcasieu gave cotidal hours very like those of Brazos Santiago and Aransas, and Galveston is later than either.

Upon the whole, then, there is a general resemblance in the motion of the two waves as assigned by observation, with some considerable discrepancies. The annexed Table No. VI. shows the difference between the establishments of the diurnal and semi-diurnal waves at the several stations.

TABLE VI.

Comparison of Establishments of Half-Day and Day Tides, in the Gulf of Mexico.

No.	Stations.	Difference between Day and Half-Day.
		h. m.
1	Cape Florida,	6 28
2	Indian Key,	8 16
3	Key West,	9 22
4	Tortugas,	9 26
5	Egmont Key,	7 54
6	Cedar Key,	8 21
7	St. Mark's,	8 39
8	St. George's Island,	5 19
9	Pensacola,	10 57
10	Fort Morgan,	10 12
11	Cat Island,	9 17
12	Southwest Pass,	10 4
13	Dernière Island,	7 19
14	Calcasieu,	5 53
15	Bolivar Point,	6 17
16	Aransas Pass,	5 59
17	Brazos Santiago,	5 4

When we come to follow these results into the discussion of the groups, they are far from satisfactory. Perhaps this was to have been expected from the circumstances before stated. The groups were nevertheless elaborately examined, though without much fruit. The table of groups is arranged as for the diurnal tides, containing, as before, a number for reference, the names of the stations, and the lati-

tude and longitude, the values of the coefficients of each, the angle made by the cotidal line with the meridian, the movement of the wave perpendicular to the cotidal line expressed by the number of minutes employed in traversing a mile, and the miles per hour. See Table VII.

TABLE VII.

Recapitulation of Groups for Half-Day Tides.

	Stations in Group.	Mean Longitude.	Mean Latitude.	Mean Cotidal Hour.	*M*	*N*	Angle.	Minutes to one Mile.	Miles per Hour.
		° ′	° ′	h. m.			° ′		
A	Cape Flor., Ind. K., K. West,	80 55	25 0	13 19	−1.515	1.151	37 14	1.902	31.5
B	Ind. K., Key West, Tortugas,	81 52	24 38	13 47	−0.551	−1.288	−66 49	1.401	42.8
C	Egm. K., Cedar K., St. Mark's,	83 18	28 51	17 23	0.049	0.935	−87 0	0.935	64.2
D	Ft. Mor., Cat Isl., S. W. Pass,	88 40	29 44	16 21	−1.260	1.887	56 16	2.269	26.4
E	Isle Dern., Calcas., Bolivar Pt.,	93 2	29 20	20 31	−1.246	−1.517	50 36	1.963	30.6
F	S. W. Pass, Dern. Isl., Calcasieu, Bolivar Pt., Brazos,	93 7	28 37	19 32	−1.243	1.488	50 07	1.939	30.9

Groups A and B, composed of Cape Florida, Indian Key, and Key West, and of Indian Key, Key West, and Tortugas, give, especially the first, plausible results, and the computed establishments vary but $1^{m}.5$, at the greatest, from the observed. I have not been able to form any satisfactory connection between these groups and those on the western coast of the peninsula. The next group, which gives a tolerable result, is Egmont Key, Cedar Keys, and St. Mark's. In this the direction of the cotidal line, the velocity, and the establishments are satisfactory.

The establishment of St. George's station is irregular, and is very probably erroneous. The semi-diurnal wave is composed of two very small ones, and it has been necessary to reconcile the discrepancies which they presented, sometimes one being the governing tide, and sometimes the other.

Group D, composed of Fort Morgan, Cat Island, and Southwest Pass, is the next, which gives a good result.

E, composed of Isle Dernière, Calcasieu, and Bolivar Point, and F, of all the stations from Southwest Pass to Brazos Santiago except Aransas, give good results as to direction and velocity, the cotidal hour of twenty for the two groups falling upon each other. The computed establishments, as in the case of the diurnal wave, present

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examined with but little satisfaction as to the conclusions; these will now be resumed, and may throw additional light upon the results at some of the doubtful stations. The interference problems will be taken up when more extended data give better hopes of a satisfactory solution of them.

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2. NOTES ON THE PROGRESS MADE IN THE COAST SURVEY, IN PREDICTION TABLES FOR THE TIDES OF THE UNITED STATES COAST. By A. D. BACHE, Superintendent U. S. Coast Survey. [Communicated by Authority of the Treasury Department.]

As soon as tidal observations had accumulated sufficiently to make the task a profitable one, I caused them to be treated, under my immediate direction, by the methods in most general acceptance. The observations of Old Point Comfort, Virginia, were among the earliest used for this purpose, and the labors of Commander Charles H. Davis, U. S. N., then an assistant in the Coast Survey, were directed to their reduction, chiefly by the graphical methods pointed out by Mr. Whewell. This work was subsequently continued by Mr. Lubbock's method, by Mr. Henry Mitchell, and next the tides of Boston harbor were taken up, as affording certain advantages in the observations themselves which could not be claimed for those of Old Point.

The system of Mr. Lubbock is founded on the equilibrium theory, and in it the inequalities are sought by arranging the elements of the moon's and sun's motions, upon which they depend. Having obtained the coefficient of the half-monthly inequality of the semi-diurnal tide at Boston, from seven years' observations, through the labors of the tidal division, and approximate corrections for the parallax and declination, I was much disappointed in attempting the verification by applying them to individual tides for a year during which we had observations. There was a general agreement on the average, but discrepancies in the single cases, which were quite unsatisfactory. Nor were these discrepancies without law, as representing their residuals by curves did not fail to show. By introducing corrections for declination and parallax of the moon increasing and decreasing, we reduced

these discrepancies; but still the results were not sufficient approximations.

With the numerical reductions of the observations before referred to, was commenced, in 1853, under my immediate direction, by Mr. L. W. Meech, a study of the theory of the tides, directed chiefly to the works of Bernouilli, La Place, Airy, Lubbock, and Whewell. The immediate object which I had in view was the application of the wave theory to the discussion of our observations. I thought that the mind of an expert mathematician, directed entirely to the theoretical portions of this work, with directions by a physicist, and full opportunities of verifying results by extended series of observations, the computations of which should be made by others in any desired form, would give, probably, the best results in this combined physical and mathematical investigation.

The general form of the different functions expressing the tidal inequalities is the same in the different theories, and may be said on the average to be satisfactory as to the laws of change which these inequalities present. Whether we adopt, with La Place, the idea that periodical forces produce periodical effects, or, with Airy, the idea that the tidal wave arrives by two or more canals, or, with Bernouilli and Lubbock, the results of an equilibrium spheroid, or, with Whewell, make a series of inequalities, semi-menstrual, parallax, and declination, with different epochs, we arrive at the same general results, that the heights and times of high water may be represented by certain functions, with indeterminate coefficients, in the form of which the theories in a general way agree. By forming equations from the observations, and obtaining the numerical values of the coefficients, by the method used so commonly in astronomical computations, the result is accomplished.

A general consideration of the co-ordinates in space of the moon and sun, without any special theory, would lead to the same result, representing the luni-tidal interval by series of sines and co-sines with indeterminate coefficients.

Calling I the luni-tidal interval from observation, λ the mean luni-tidal interval, H the clock time of observation, $l't$ the moon's longitude, P' the moon's parallax, and $\delta P'$ the hourly variation of the

moon's parallax, we have, for the formula representing the correction for half-monthly inequality,

$$s \sin 2H + s_1 \cos 2H;$$

for the moon's parallax correction,

$$p\,(P' - 57') + p_2\,(P' - 57') \sin 2H + p_3\,(P' - 57') \cos 2H;$$

for the correction for hourly difference of the moon's parallax,

$$p_1\,(\delta P') + p_4\,(\delta P') \sin 2H + p_5\,(\delta P') \cos 2H;$$

and for the moon's declination corrections, including the rate of change,

$$d \sin 2\,l't + d_1 \cos 2\,l't + q_1 \sin 2\,l't \sin 2H + q_2 \sin 2\,l't \cos 2H + q_3 \cos 2\,l't \sin 2H + q_4 \cos 2\,l't \cos 2H.$$

There are corresponding terms for the inequalities produced by the sun's action.

The whole formula takes the form,

$$I = \lambda + s \sin 2H + s_1 \cos 2H \Big\} \text{ Mean interval and half-monthly inequality correction.}$$

$$\left.\begin{array}{r} p\,(P' - 57') + p_2\,(P' - 57') \sin 2H \\ + p_3\,(P' - 57') \cos 2H \end{array}\right\} \text{ Moon's parallax correction.}$$

$$p_1\,(\delta P') + p_4\,(\delta P') \sin 2H + p_5\,(\delta P') \cos 2H \Big\} \text{ Hourly diff. of Moon's parallax correction.}$$

$$\left.\begin{array}{l} d \sin 2\,l't + q_1 \sin 2\,l't \sin 2H + q_2 \sin 2\,l't \cos 2H \\ d_1 \cos 2\,l't + q_3 \cos 2\,l't \sin 2H + q_4 \cos 2\,l't \cos 2H \end{array}\right\} \text{ Moon's declination corrections.}$$

$$\left.\begin{array}{l} + t_1 \sin l\,t \sin 2H + t_2 \sin l\,t \cos 2H \\ + t_3 \cos l\,t \sin 2H + t_4 \cos l\,t \cos 2H \end{array}\right\} \text{ Sun's parallax corrections.}$$

$$\left.\begin{array}{l} + Q_1 \sin 2\,l\,t \sin 2H + Q_2 \sin 2\,l\,t \cos 2H \\ + Q_3 \cos 2\,l\,t \sin 2H + Q_4 \cos 2\,l\,t \cos 2H \end{array}\right\} \text{ Sun's declination corrections.}$$

The grouping of the observations of one year at Boston, to apply this method, the formation of the equations, and their solution by the method of indirect elimination, has been the work of Mr. R. S. Avery, who has labored most assiduously and successfully, ingeniously checking his work where the system of checks could be applied, at every step. He has determined the values of λ and of the coefficients for Boston as follows: —

$$\lambda = +38.47, \quad d = -3.17, \quad d_1 = -35.62,$$

$$p = -0.93, \quad p_1 = -1.56, \quad s = -19.49, \quad s_1 = +11.97,$$

$$p_2 = +1.31, \quad p_3 = -1.21, \quad p_4 = +0.23, \quad p_5 = +0.60,$$

$$q_1 = -7.17, \quad q_2 = +1.81, \quad q_3 = +2.91, \quad q_4 = -1.99,$$

$$t_1 = +5.14, \quad t_2 = +2.26, \quad t_3 = -0.76, \quad t_4 = -1.37,$$

$$Q_1 = -21.25, \quad Q_2 = +28.39, \quad Q_3 = +27.10, \quad Q_4 = +23.13.$$

There are propositions for facilitating this work, growing out of the experience acquired in the computations, but requiring more examination than they have yet received before pronouncing upon them. It is possible that, by applying Lubbock's method of averages to some of the terms, approximate values may be found more readily than by the method we have employed. Two additional terms for the sun's declination, $D \sin 2\,lt$, and $D_1 \cos 2\,lt$, will be introduced. I present to the Association the tables computed by Mr. Avery for applying this method to the prediction of the tides at Boston harbor.

In order to test the coefficients, computations were made for different parts of the months of the year 1853 for which we have observations. Transit C was used as the transit of reference.

The differences between the predicted and observed results are shown in the annexed table, the first column of which contains the dates, the second the computed, the third the observed, and the fourth the observed less the computed results.

From this table it appears that in twenty pairs of tides, the morning and afternoon results being grouped in the fifth column to get rid of the diurnal inequality, there are two differences of less than 2^m, thirteen of more than 2^m and less than 4^m, three of more than 4^m and less than 10^m, and two of more than 10^m. The probable error of the prediction of a single pair of tides is $4^m.12$.

These laborious researches are still in progress, but I have thought that the results already obtained required a notice of them, and a recognition of the labors of Messrs. Meech and Avery.

Comparison of Observed and Predicted Times of High Water, Boston, Massachusetts.

Date. 1858.	Time of High Water. Predicted.	Observed.	Difference Obs. Pr.	Mean of Pairs.
	h. m.	h. m.	m.	m.
March . . . 21	8 4.7	8 3	— 1.7	
" . . . 21	20 32.9	20 32	— 0.9	— 1.3
" . . . 25	11 28.0	11 21	— 7.0	
" . . . 25	23 49.8	23 48	— 1.8	— 4.4
" . . . 29	2 21.7	2 20	— 1.7	
" . . . 29	14 45.3	14 42	— 3.3	— 2.5
April . . . 2	6 16.9	6 21	4.1	
" . . . 2	18 51.5	18 59	7.5	5.8
" . . . 6	10 19.8	10 18	— 1.8	
" . . . 6	22 40.2	22 36	— 4.2	— 3.0
June . . . 21	11 18.4	11 18	— 0.4	
" . . . 21	23 44.7	23 49	4.3	2.0
" . . . 25	2 34.5	2 39	4.5	
" . . . 25	15 2.3	15 3	0.7	2.6
" . . . 29	5 57.7	6 7	9.3	
" . . . 29	18 24.3	18 37	12.7	11.0
July . . . 3	9 27.4	9 31	3.6	
" . . . 3	21 52.2	21 53	0.8	2.2
" . . . 7	0 0.1	0 3	2.9	
" . . . 7	12 10.3	12 12	1.7	2.3
September . . 24	3 59.4	4 7	7.6	
" . . . 24	16 24.8	16 24	— 0.8	3.4
" . . . 28	7 39.7	7 44	4.3	
" . . . 28	20 11.6	20 15	3.4	3.9
October . . 2	11 6.1	11 4	— 2.1	
" . . 2	23 31.1	23 30	— 1.1	— 1.6
" . . . 6	1 44.7	1 40	— 4.7	
" . . . 6	14 7.7	14 7	— 0.7	— 2.7
" . . . 10	5 24.5	5 19	— 5.5	
" . . . 10	17 57.8	17 58	0.2	— 2.7
December . . 21	3 7.2	3 9	1.8	
" . . . 21	15 28.4	15 30	1.6	1.7
" . . . 25	6 32.6	6 31	— 1.6	
" . . . 25	19 0.7	18 52	— 8.7	— 5.2
" . . . 29	10 22.4	10 26	3.6	
" . . . 29	22 53.3	22 42	—11.3	— 3.9
January . . . 2	1 29.4	1 2	—27.4	
" . . . 2	13 54.0	13 41	—13.0	—20.2
" . . . 6	4 45.8	4 53	7.2	
" . . . 6	17 33.9	17 30	— 3.9	1.7

Final Mean, ... 0.5

Probable error, minutes 4.12

Number of differences less than two minutes = 2

Number of differences more than two minutes and less than four = 13

" " " four " " " ten = 8

" " " ten " = 2

3. OBSERVATIONS TO DETERMINE THE CAUSE OF THE INCREASE OF SANDY HOOK, MADE BY THE COAST SURVEY FOR THE COMMISSIONERS ON HARBOR ENCROACHMENTS OF NEW YORK. By A. D. BACHE, Superintendent U. S. Coast Survey.

Abstract.

IT is known as one of the developments of the Coast Survey, that the peninsula of Sandy Hook is gradually increasing, growing to the northward in the main ship-channel. A spot north of the Hook, where there was forty feet of water when Captain Gedney made his survey, in less than ten years was nearly bare at low water. The importance of determining the cause of this increase, as leading to the means of controlling it, cannot be over-estimated. The Commissioners on Harbor Encroachments had early attended to this matter, and requested that the necessary observations for its investigation should be made. These were made, under my immediate direction, by Henry Mitchell, one of the sub-assistants in the Coast Survey, with all desirable zeal and ability. Various causes had been assigned for this growth, by the action of the waves and winds sometimes on the outer side and sometimes on the inside of the Hook. The effect of the opening and closing of Shrewsbury Inlet had also been insisted upon. To examine these and other probable causes, laborious observations of tides and currents had been made in the vicinity, at stations marked upon the map now exhibited to the Association. Careful measurements of the low-water line had also been made in connection with these observations, and with others of the force and direction of the wind. Objects easily distinguished from the sand, and of various specific gravities and shapes, had been deposited near the shore of the Hook to determine the power and direction of transportation of matter along the shores of the Hook. It is easy to see how laborious all of these observations are, and that some of them are obtained with considerable danger. Hence the credit to be given to Mr. Mitchell may be measured. The results of these observations have not yet been worked out in all their detail, but the conclusions from them are perfectly safe, and are of the highest importance. It turns out that this growth of the Hook is not an accidental phenomenon, but goes on regularly, and according to determinable laws. The amount of in-

crease depends upon variable causes, but the general fact is, that it increases year by year; and the cause of this is a remarkable northwardly current, the amount and duration of which these observations assign along both shores of the Hook, the outer one extending across the whole breadth of False Hook channel with varying velocity, and the one inside of the Hook extending nearly one third of the distance across Sandy Hook bay. These currents run to the north during both ebb and flood tide, with varying rates, and result from those tides directly and indirectly. The inner current is the one by which the flood and ebb tides draw, by the lateral communication of motion, the water from Sandy Hook bay; and the outer is similarly related to those tides as they pass False Hook channel. The velocities and directions which have been found, prove this conclusively. An important observation for navigation results from this; for more than seven hours out of the twelve there is a northwardly current running through False Hook channel, which assists vessels entering New York harbor on the ebb tide, and is to be avoided in passing out with the ebb. This northwardly current runs on the inside for eleven hours out of the twelve. It is the conflict of these two northwardly currents outside and inside, and the deposit of the materials which they carry to the point of the Hook, which cause its growth. Within a century it has increased nearly a mile, and at the rate of about one sixteenth of a mile, on the average, in twelve years. Flynn's Knoll, on the north side of the main ship-channel, does not give way as much as the point of the Hook advances. The importance of watching this movement cannot, therefore, be overstated. The mode of controlling the growth is obvious from the result obtained. The observations are still continued, to obtain the necessary numerical results.

4. NOTICE OF OBSERVATIONS TO DETERMINE THE PROGRESS OF THE TIDAL WAVE OF THE HUDSON RIVER, MADE BY THE COAST SURVEY FOR THE COMMISSIONERS ON HARBOR ENCROACHMENTS. By A. D. BACHE, Superintendent U. S. Coast Survey.

Abstract.

PROFESSOR BACHE explained the importance of a knowledge of the movement of the tide-wave up the Hudson River to the determination of the shore line of New York bay and harbor, and the subject of encroachment upon the area of the harbor, and stated that the New York Commissioners had directed a full series of observations to be made for the examination of this point in the bearing just referred to, and also on the character of the improvements projected for the Hudson River at the Overslaugh, and indeed in the whole distance from Troy to New Baltimore. Nine tidal stations were in the course of occupation between Governor's Island, New York, and Greenbush, opposite Albany. At the two terminal stations Saxton's self-registering gauges were placed, and he had expected to invite the members to see the Albany gauge; but the late freshet in the river had required its removal for the present. Professor Bache explained the selections made of the localities of the tidal stations, and the reasons for their special positions, and stated that the results of the work would hereafter be laid before the Association.

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5. SUPPLEMENT TO THE PAPER ON THE "SECULAR VARIATION IN THE MAGNETIC DECLINATION ON THE ATLANTIC AND GULF COAST OF THE UNITED STATES, FROM OBSERVATIONS IN THE 17TH, 18TH, AND 19TH CENTURIES," PUBLISHED IN THE PROVIDENCE PROCEEDINGS OF THE ASSOCIATION. By CHARLES A. SCHOTT, U. S. Coast Survey. (By Permission of the Superintendent of the U. S. Coast Survey.)

THE former discussion of the secular change of magnetic declination having pointed out where new observations would be of special

value, such additional determinations have been made by myself at a number of stations, under the direction of Professor Bache. By their introduction, the conclusions previously arrived at have been materially improved in accuracy, and have received important additions, which it is the purpose of this paper briefly to state, with special reference to the formula and notation used in the former discussion.

This supplement is confined to the subdivisions (b) and (d), and includes new determinations of the declination at Burlington, Vt., Boston, Providence, New Haven, New York, Philadelphia, Cape May, and Washington City, made during the months of August and September, 1855.

The results of the rediscussion are presented in the following tables, which partly take the place of those given on pages 168 and 169 of the Proceedings of the Ninth Meeting.

Synopsis of Results of the Discussion for Secular Variation at Thirteen Stations.

No.	Station.	Latitude.	Longitude.	Declination.
		° ′	° ′	
1	Burlington, Vt.	44 28	73 10	$D = +8.22 + 0.0494(t-1830) + 0.000831(t-1830)^2$
2	Boston,	42 20	71 2	" $+8.33 + 0.0622$ " $+0.000596$ "
3	Cambridge,	42 23	71 7	" $+8.55 + 0.0702$ " $+0.000720$ "
4	Providence,	41 50	71 24	" $+7.51 + 0.0664$ " $+0.000852$ "
5	New Haven,	41 17	72 55	" $+5.40 + 0.0475$ " $+0.000814$ "
6	New York,	40 43	74 0	" $+5.07 + 0.0536$ " $+0.000800$ "
7	Hatborough,	40 7	75 8	" $+2.86 + 0.0683$ " $+0.001169$ "
8	Philadelphia,	39 58	75 10	" $+2.52 + 0.0595$ " $+0.001232$ "
9	Cape May,	38 56	74 57	" $+0.88 + 0.0532$ " $+0.000809$ "
10	Washington,	38 53	77 1	" $+0.88 + 0.0412$ " $+0.001080$ "
11	Charleston,	32 45	79 51	" $-3.33 + 0.0485$ " $+0.000722$ "
12	Mobile,	30 14	88 0	" $-7.24 + 0.0072$ " $+0.000123$ "
13	Havana, Cuba,	23 9	82 22	" $-6.08 + 0.0098$ " $+0.000255$ "

No.	Station.	ϵ_0	τ	d	Annual Variation.	V in 1850.
		′		°		′
1	Burlington, Vt.	± 10	1800.3	+7.49	$V = +0.049 + 0.00166\,(t-1830)$	+4.9
2	Boston,	± 12	1777.8	+6.72	" $+0.062 + 0.00119$ "	+5.2
3	Cambridge,	± 5	1781.2	+6.83	" $+0.070 + 0.00144$ "	+5.9
4	Providence,	± 7	1791.0	+6.14	" $+0.070 + 0.00178$ "	+6.0
5	New Haven,	± 11	1800.8	+4.71	" $+0.047 + 0.00163$ "	+4.8
6	New York,	± 15	1796.5	+4.15	" $+0.054 + 0.00160$ "	+5.2
7	Hatborough,	± 8	1799.5	+1.87	" $+0.068 + 0.00224$ "	+6.8
8	Philadelphia,	± 21	1805.9	+1.80	" $+0.060 + 0.00246$ "	+6.5
9	Cape May,	....	1797.1	+1.00	" $+0.053 + 0.00162$ "	+5.1
10	Washington,	....	1810.9	+0.49	" $+0.041 + 0.00216$ "	+5.0
11	Charleston,	± 10	1796.4	−4.16	" $+0.048 + 0.00144$ "	+4.6
12	Mobile,	....	1800.6	−7.35	" $+0.007 + 0.00024$ "	+0.7
13	Havana, Cuba,	....	1810.8	−6.17	" $+0.010 + 0.00051$ "	+1.2

The average τ from the first seven stations is 1792.4, and from the last six 1803.6, and the mean $\tau = 1797.6 \pm 1.8$ years (see Proceedings of Ninth Meeting, p. 171, note). To the northeastward of Philadelphia, within the geographical limits of the discussion, we may therefore assume the minimum to have taken place about five years earlier, and to the southward of that place, about the same number of years later than the mean epoch.

Two observations by Dr. J. Locke, not obtained in time for introduction into the discussion, are represented by the above formulæ as follows: — At Burlington, Vt., June 26th, 1845, observed declination 9° 22′ west, computed 9° 11′ west; at Cambridge, June 2d, 1845, observed declination 9° 32′ west, computed 9° 49′ west. The last observation appears to give too low a value, since Mr. Bond had obtained 9° 39′ in the preceding year.

(To *d*.) The re-discussion of the coefficient C' in regard to the geographical position of the stations furnished the following numerical result for the coefficients x, y, z, u and v: —

$$10{,}000\ C' = +\ 556 - 10.4\ (l - 37°.5) - 44.4\ (m - 76°.1)\cos l - 1.65\ (l - 37°.5)^2 - 0.08\ (m - 76°.1)^2 \cos^2 l;$$

or,

$$C' = +\ 0.0556 - 0.00104\ \lambda - 0.00444\ \mu - 0.000165\ \lambda^2 - 0.000008\ \mu^2;$$

(see Proceedings of the Ninth Meeting, p. 174, note;) which equation satisfied the coefficients C' (or the former y) as follows: —

No.	Station.	C'	C' computed.	Δ
1	Burlington, Vt.,	0.0494	0.0496	+0.0002
2	Boston,	0.0622	0.0636	+0.0014
3	Cambridge,	0.0702	0.0629	−0.0073
4	Providence,	0.0664	0.0634	−0.0030
5	New Haven,	0.0475	0.0600	+0.0125
6	New York,	0.0536	0.0577	+0.0041
7	Hatborough,	0.0683	0.0553	−0.0130
8	Philadelphia,	0.0595	0.0551	−0.0044
9	Cape May,	0.0532	0.0534	+0.0002
10	Washington, D. C.,	0.0412	0.0507	+0.0095
11	Charleston,	0.0485	0.0431	−0.0054
12	Mobile,	0.0072	0.0129	+0.0057
13	Havana, Cuba,	0.0098	0.0105	+0.0007

The last column gives $\varepsilon_{C'} = \pm\ 0.0057$, which approaches still closer to $\varepsilon_y = \pm\ 0.0046$, as deduced from the differences at each sta-

tion. The second co-efficient C'' has been deduced from the mean of the values for C' and C' computed, and was found as follows: —

From	Burlington,	$n = 0.016$
"	Boston,	0.010
"	Cambridge,	0.012
"	Providence,	0.013
"	New Haven,	0.015
"	New York,	0.016
"	Hatborough,	0.019
"	Philadelphia,	0.021
"	Cape May,	0.015
"	Washington,	0.023
"	Charleston,	0.016
"	Mobile,	0.014
"	Havana,	0.025

where $C'' = n\ C'$.

The values just deduced should be used in connection with the formulæ

$$D = C + C'\ (t - 1830) + C''\ (t - 1830)^2$$

and

$$v = C' + 2\ C''\ (t - 1830).$$

The following comparison of the latest observations, with the values computed for the same date, will show that the latter exceed the former, almost without exception, — an indication that the rate of increase has begun to lessen, and that the expectation of the point of inflexion in the curve, representing the rate of change about the time 1867 ± 15 was not premature (see Proceedings of Ninth Meeting, page 167).

Station.	D computed for 1855.5.	D observed in 1855.5.	C. — O.
	°	°	°
Burlington, Vt.,	+10.02	+ 9.95	+0.07
Albany,	8.45	7.91	+0.54
Salem,	11.12	10.83	+0.29
Boston,	10.30	10.23	+0.07
Cambridge,	10.76	10.90	—0.14
Providence,	9.68	9.52	+0.16
Nantucket,	10.15	9.98	+0.17
New Haven,	7.16	7.05	+0.11
New York,	6.97	6.72	+0.25
Philadelphia,	4.85	4.53	+0.32
Washington,	+ 2.63	+ 2.40	+0.23

The average difference is + 0°.19 = 11′. The precise date of

the maximum annual change cannot now be ascertained, and must be left to a future series of observations; but it is recommended, in the application of the formulæ for any period subsequent to 1850, to compute the change for a corresponding interval prior to that date, and add it to the declination in 1850.

Thus, for example, the declination at Boston in 1870 will be found by computing the increase for twenty years prior to 1850, and adding the same to the declination for 1850; or $9°.81 + 1°.48 = 11°\ 18'$ W.

Without stepping off the positive ground heretofore occupied, it will be interesting to remark the following epochs: —

		Differences.
Deduced maximum declination in	1679 ± 10 years.	
		62 years.
Known first point of inflexion,	1741 ± 10 "	
		57 "
Known minimum declination,	1798 ± 2 "	
		52 "
Supposed second point of inflexion,	1850.	

From which it would seem that the periods are diminishing, or the velocity of the secular variation is increasing, which latter remark is sustained by the comparison of $V_{1741} = -4'.6$ with $V_{1850} = +6'.8$ or $+5'.9$, as deduced from all the Northern stations. The prediction of the next maximum is too hazardous to deserve our attention at present.

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6. Discussion of the Secular Variation of the Magnetic Inclination in the Northeastern States. By Charles A. Schott, U. S. Coast Survey. (Communicated by Permission of Professor A. D. Bache, Superintendent U. S. Coast Survey, and by Authority of the Treasury Department.)

The following paper on the secular variation of the magnetic inclination near the Atlantic coast, between latitudes 38° and 44°, forms a part of the general discussion of the magnetic observations of the Coast Survey, under the direction of the Superintendent, the publication of which was commenced in the Superintendent's annual report for 1855, and which will be continued in the report for 1856.

While the observations of declination reach back as far as the seventeenth century, and are quite numerous since the latter half of the eighteenth, the observations for inclination are of but recent date. Near our Atlantic coast, thirty or thirty-five years include the whole period, taking no account of three observations about 1782, at Cambridge. Fortunately for our knowledge, the secular variation within this short period has passed a turning-point, the epoch of which has been fully established.

Here, as in the declination, Professor Loomis has contributed a large share in observing, collecting, and discussing magnetic dips, and we are also indebted to him for the construction of an isoclinal map. Professor Loomis says: "From these observations [collected by him], when compared with those of Long's expedition, we may assume the diminution of the dip from 1819 to 1839 to be at the rate of 1'.5 a year." (Silliman's Journal, XXXIX., 1840, On the Variation and Dip of the Magnetic Needle in the United States, by E. Loomis.)

It does not appear that later a second effort was made to follow these changes of the dipping needle, probably on account of the small change and stationary period soon afterwards reached.

It must be considered as fortunate, that the dip observations at the Toronto Observatory commenced as early as 1841, and therefore include the turning epoch, although from these observations alone it could not be clearly made out. Colonel Sabine remarks (page lxxxviii. of Observations made at the Magnetical and Meteorological Observatory at Toronto, Canada, Vol. II., 1843–45, London, 1853): "On a first inspection of the values of the inclination in the years from 1841 to 1852 inclusive, we might be led to infer that in 1843 or 1844 the secular change at Toronto reached a turning epoch, and that, from having been previously a decrease, it became subsequently an increase of inclination. It is possible, however, that the facts may admit, and may hereafter receive, a different explanation." He then goes on to show that the change may be owing to disturbances, and finally remarks: "In the mean time, considering the small amount of the apparent irregularities, together with the variety of needles employed in the observations of the different years and the consequent possibility of defective intercomparability, we may perhaps take as the best present approximation a uniform increase of inclination."

It will be seen further on, that the first supposition, that of a minimum about 1843, was the correct one, and that this fact is supported by a number of observations at other stations, and in particular at Philadelphia, where we have another excellent series of observations made under the direction of Professor A. D. Bache. This series also includes the minimum, the establishment of which beyond doubt may be considered as the principal result of the present investigation. From a cursory examination of the observations at New York and Cambridge, the epoch of this minimum was recognized and communicated to the Superintendent in October last.

The observations used in this discussion have been collected with care, and it is believed include nearly all that have been published; the results are based upon one hundred and sixty-one separate determinations of dip. The mode of discussion and the formulæ used being similar to those employed in my discussion of the secular variation of the declination in the Coast Survey Report for 1855 (and in Proceedings of the Ninth Meeting of the American Association, 1855), no further explanation is deemed requisite here.

It was found that at present the inclination could be represented by the formula $I = i_1 + x + y\,(t - t_0) + z\,(t - t_0)^2$, the same as used by Professor Hansteen in his paper "On the Changes in the Magnetic Inclination in the Northern Temperate Zone." (*Astronomische Nachrichten*, Nos. 947, 948, and 954.) The epoch 1840, to which the results of the separate stations were reduced in Professor Hansteen's paper, also suited the present investigation. One locality, New York, is included in both papers, of which more hereafter.

The observations at the several stations admitting of discussion here follow.

The column headed Observed inclinations, in the following tables, contains in many cases means of inclinations observed in the same year or otherwise combined, the space here not admitting of full details.

Secular Change of the Magnetic Dip at Toronto, Canada.

The observations can be found in Vol. II., 1843, 1844, 1845, of Observations at the Magnetical and Meteorological Observatory at Toronto in Canada, London, 1853; in Silliman's Journal, Vol. IV., 1847;

and in the Transactions of the American Philosophical Society, Vol. IX., 1846. They can be represented by the formula

$$I = 75°.29 - 0.01441\ (t - 1840) + 0.001636\ (t - 1840)^2.$$

The following table contains the observed and computed inclinations: —

t	I Observed.	I Computed.	Δ
	°	°	°
1841.5	75.28	75.27	—0.01
1842.5	75.27	75.26	—0.01
1843.0	75.26	75.26	0.00
1843.5	75.24	75.25	+0.01
1844.5	75.23	75.25	+0.02
1845.5	75.26	75.26	0.00
1846.5	75.25	75.26	+0.01
1847.5	75.26	75.27	+0.01
1848.5	75.30	75.28	—0.02
1849.5	75.31	75.30	—0.01
1850.5	75.33	75.32	—0.01
1851.5	75.34	75.34	0.00
1852.5	75.34	75.36	+0.02

The probable error of any single result is $\pm$ 0′.6.

Secular Change of the Magnetic Dip at Albany and Greenbush, New York.

The observations were extracted from the Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. III., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. IV., 1847; and Coast Survey Report for 1855.

They are represented by the formula

$$I = 74°.70 - 0.0086\ (t - 1840) + 0.00257\ (t - 1840)^2,$$

which expression represents the observations as follows: —

t	I Observed.	I Computed.	Δ
	°	°	°
1833.4	74.85	74.86	+0.01
1837.1	74.76	74.74	—0.02
1842.0	74.70	74.69	—0.01
1844.5	74.69	74.71	+0.02
1855.6	75.19	75.19	0.00

The probable error of any single result is $\pm$ 0′.9.

Secular Change of the Magnetic Dip at Cambridge, Mass.

The observations were taken from the Memoirs of the American Academy, 1846; Encyclopædia Metropolitana, 1848; Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. IV., 1847; Smithsonian Contributions to Knowledge, Vol. III., 1852; and Coast Survey Report for 1855.

The observations have been represented by the following formula:

$$I = 74°.34 - 0.02840\,(t - 1840) + 0.002400\,(t - 1840)^2.$$

The table shows the comparison of the observed and calculated inclinations: —

t	I Observed.	I Computed.	Δ
	°	°	°
1839.7	74.31	74.35	+0.04
1840.5	74.36	74.33	−0.03
1841.6	74.22	74.30	+0.08
1842.4	74.24	74.28	+0.04
1844.9	74.30	74.26	−0.04
1845.5	74.32	74.26	−0.06
1846.7	74.21	74.26	+0.05
1855.6	74.48	74.48	−0.00

The probable error of any single value is $\pm$ 1′.8.

Secular Change of the Magnetic Dip at Providence, R. I.

The observations can be found in Silliman's Journal, Vol. XLIII., 1842; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. VII., 1840; and in the Coast Survey Report for 1855.

They are represented by the formula

$$I = 73°.99 - 0.0040\,(t - 1840) + 0.00141\,(t - 1840)^2.$$

Comparison of observed and computed values: —

t	I Observed.	I Computed.	Δ
	°	°	°
1834.6	74.05	74.06	+0.01
1839.7	73.99	73.99	0.00
1842.5	74.00	73.99	−0.01
1855.6	74.27	74.27	0.00

$$\epsilon_0 = \pm\ 0'.7.$$

Secular Variation of the Magnetic Dip at West Point and Coldspring, N. Y.

References to observations: Silliman's Journal, Vol. XLIII., 1842; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 73°.43 - 0.00165\ (t - 1840) + 0.002080\ (t - 1840)^2.$$

The agreement with the observed dip is as follows: —

t	I Observed.	I Computed.	Δ
	°	°	°
1833.9	73.53	73.52	—0.01
1839.8	73.46	73.43	—0.03
1840.5	73 33	73.43	+0.10
1842.5	73.51	73.44	—0.07
1855.6	73.91	73.91	0.00

The probable error of any single value is $\pm$ 3′.1.

Secular Change of the Magnetic Dip at New Haven, Conn.

References to observations: Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. IV., 1847; and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 73°.42 + 0.0020\ (t - 1840) + 0.00117\ (t - 1840)^2.$$

Comparison of observed and computed dips: —

t	I Observed.	I Computed.	Δ
	°	°	°
1839.7	73.45	73.42	—0.03
1842.4	73.44	73.43	—0.01
1844.5	73.40	73.45	+0.05
1848.6	73.54	73.52	—0.02
1855.6	73.74	73.73	—0.01

$$\epsilon_0 = \pm\ 2'.2.$$

Secular Change of the Magnetic Dip at New York.

References of observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; Ibid., Vol. IX., 1846; a communication by Professor Hansteen, dated October 15th, 1854; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. XLIII., 1842; Ibid., Vol. XXII., 1832; Ibid., Vol. IV., 1847; and Coast Survey Report for 1855.

These observations have been represented by the formula

$$I = 72°.69 - 0.00491\ (t - 1845) + 0.001141\ (t - 1845)^2,$$

as follows: —

t	I Observed.	I Computed.	Δ
	°	°	°
1823.9	73.24	73.31	+0.07
1831.3	73.00	72.98	−0.02
1833.4	73.03	72.91	−0.12
1835.0	72.86	72.86	0.00
1839.7	72.87	72.75	−0.12
1841.3	72.68	72.73	+0.05
1842.5	72.64	72.71	+0.07
1844.4	72.62	72.70	+0.08
1845.5	72.68	72.69	+0.01
1846.6	72.65	72.69	+0.04
1845.6	72.83	72.77	−0.06

The probable error of any single value is ± 3′.3. The above formula, when transformed for the epoch 1840, becomes

$$I = (i_0 - 5\ y + 25\ z) + (y - 10\ z)\ (t - 1840) + z\ (t - 1840)^2;$$

or numerically,

$$I = 72°.75 - 0.01632\ (t - 1840) + 0.001141\ (t - 1840)^2.$$

Secular Change of the Magnetic Dip at Philadelphia, Pa.

References to observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. XLII., 1842; Ibid., Vol. IV., 1847; Observations at Magnetic Observatory, Girard College, Philadelphia, 1840–45 (Washington, 1847); and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 71°.99 + 0.0010\ (t - 1840) + 0.00124\ (t - 1840)^2.$$

The positive sign of y probably arises from too small a dip in 1834,

which also causes the minimum to shift to an earlier date than the other stations indicate.

t	I Observed.	I Computed.	Δ
	°	°	°
1834.5	72.00	72.02	+0.02
1840.2	72.00	71.99	—0.01
1841.3	71.97	71.99	+0.02
1842.5	72.00	72.00	0.00
1843.6	71.96	72.01	+0.05
1844.4	72.03	72.02	—0.01
1846.4	72.02	72.05	+0.03
1855.7	72.30	72.31	+0.01

The probable error of any single value is $\pm$ 1'.0.

If we consider the important series of dips observed at the Girard Observatory by itself, we find the secular change between 1842 and 1844 is much masked by the annual inequality and other irregularities, as will be seen from the separate results. The quarterly means probably indicate the minimum about the autumn of 1843; in the recapitulation, however, I have preferred to give the result derived from the discussion of all observations.

Secular Change of the Magnetic Dip at Washington, D. C.

References to observations: Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. I., 1846; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. IX., 7th series, 1844; Ibid., Vol. VIII., 1843; Senate Document, 2d Session, 28th Congress, 1844–45; and Coast Survey Report of 1855.

The following formula represents these observations:

$$I = 71°.29 - 0.01496\ (t - 1840) + 0.001728\ (t\ 1840)^2;$$

with the differences: —

t	I Observed.	I Computed.	Δ
	°	°	°
1839.2	71.29	71.30	+0.01
1841.0	71.30	71.27	—0.03
1842.5	71.22	71.26	+0.04
1844.4	71.27	71.25	—0.02
1851.5	71.32	71.34	+0.02
1852.4	71 39	71.37	—0.02
1855.7	71.47	71.48	+0.01

The probable error of any single result is $\pm$ 1'.2.

SECULAR CHANGE OF THE MAGNETIC DIP AT BALTIMORE, MD.

References to observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; and Silliman's Journal, Vol. IV., 1847.

For want of an observation at the present time, the formula expressing the variation in the dip can only be approximate; the observations are well represented by

$$I = 71°.72 - 0.0357\ (t - 1840) + 0.00104\ (t - 1840)^2,$$

which agrees very well in regard to the curvature (z) with the rest of the stations.

RECAPITULATION OF RESULTS.

TABLE No. I.

Geographical Position of Stations, and Number of Observations for Dip at each.

No.	Station.	Latitude.	Longitude.	No. of Observations.
		° ′	° ′	
1	Toronto, Canada,	43 33	79 20	15
2	Albany (and Greenbush), N. Y.,	42 37	73 44	9
3	Cambridge (and Boston), Mass.,	42 22	71 07	17
4	Providence, R. I.,	41 50	71 24	4
5	West Point (and Coldspring), N. Y.,	41 25	73 57	6
6	New Haven, Conn.,	41 17	72 55	10
7	New York, N. Y.,	40 43	74 00	22
8	Philadelphia, Pa.,	39 58	75 10	45
9	Washington (and Georgetown), D. C.,	38 53	77 01	17
10	Baltimore, Md.,	39 18	76 37	16

TABLE No. II.

Formula expressing the Inclination at the several Stations, arranged in the order of their Magnetic Latitude.

Toronto,	$I = 75°.29 - 0.0144\ (t - 1840) + 0.00164\ (t - 1840)^2$.
Albany,	$I = 74.70 - 0.0086\ (t - 1840) + 0.00257\ (t - 1840)^2$.
Cambridge,	$I = 74.34 - 0.0284\ (t - 1840) + 0.00240\ (t - 1840)^2$.
Providence,	$I = 73.99 - 0.0040\ (t - 1840) + 0.00141\ (t - 1840)^2$.
West Point,	$I = 73.43 - 0.0016\ (t - 1840) + 0.00208\ (t - 1840)^2$.
New Haven,	$I = 73.42 + 0.0020\ (t - 1840) + 0.00117\ (t - 1840)^2$.
New York,	$I = 72.75 - 0.0163\ (t - 1840) + 0.00114\ (t - 1840)^2$.
Philadelphia,	$I = 71.99 + 0.0010\ (t - 1840) + 0.00124\ (t - 1840)^2$.
Washington,	$I = 71.29 - 0.0150\ (t - 1840) + 0.00173\ (t - 1840)^2$.

The agreement of the values for y and z must be considered as very satisfactory. The shifting of the epoch t_0 by a few years would give equal sign to y for all stations; but by so doing nothing is gained. The coefficients z, expressing the curvature, are still more accordant than the y's.

TABLE No. III.

Showing the Probable Error ϵ_0 of any single Determination for Dip (or in many cases of the Mean of several Observations at the same time), the epoch T of the Minimum Dip, and the Annual Variation V in the current Year.

Station.	ϵ_0	T	V 1856.
Toronto,	± 0′.6	1844.7	+ 2′.1
Albany,	0.9	1841.7	+ 4.3
Cambridge,	1.8	1845.9	+ 2.9
Providence,	0.7	1841.4	+ 2.9
West Point,	2.4	1840.4	+ 3.9
New Haven,	2.2	1839.2	+ 2.3
New York,	3.3	1847.1	+ 1.2
Philadelphia,	1.0	1839.6	+ 2.2
Washington,	± 1.2	1844.3	+ 2.4
Mean,	± 1.6	1842.7 ± 0.7	+ 2.7

Professor Hansteen, in his paper in the *Astronomische Nachrichten*, alluded to before, obtained for New York a result contradictory of the above well-established one, and supposes the dip to attain a *maximum* value in 1822.3. This is due to the small number and uncertainty of the observations used. The recent observations have been furnished to him at his request, and he will probably see cause to modify his former conclusions on this point. We see thus that the inclination has become stationary 1842.7 — 1797.2, or 45½ years after the declination was in a similar condition.

In the Northeastern States the inclination reached a minimum about the middle of the year 1843, and from a previous decrease has become increasing since that time, with a gradually increasing rate.

The formulæ deduced apply with certainty for ten or fifteen years before and after the year 1843, and in the absence of other information may be extended as far back as the commencement of the present century.

I append a few remarks in reference to the secular change in the Western part of this continent. While at St. Louis and other places in the Western States the dip was decreasing since 1819 until about 1842, we find the same thing to have taken place on the Western coast; and from the scanty material available in that region, we have sufficient proof of the fact, that since the close of the last century the dip was decreasing at an average rate of about 2′ a year, and, after having become stationary nearly about the same time as on the Atlantic coast, is now on the increase. Thus at San Diego the minimum

took place about 1844, and even as high north as Sitka this epoch appears to have obtained. Professor Hansteen, in No. 947 *Ast. Nach.*, calculates for this place,

$$I = 75°.84 + 0.0084\ (t - 1840) + 0.00068\ (t - 1840)^2,$$

and consequently $T = 1833.8 \pm 6.4$ years.

Thus it appears with great probability that, over the northern part of the United States, from ocean to ocean, the secular change of the inclination has been following a uniform law, reversing its direction about the same period.

In regard to the Southern States, there is not a sufficient number of observations to permit a conjecture as to the secular variation of the dipping needle.

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7. On the General Distribution of Terrestrial Magnetism in the United States, from Observations made in the United States Coast Survey and Others. By A. D. Bache, Superintendent, and J. E. Hilgard, Assistant.

During the progress of the Coast Survey within the last twelve years, observations of the magnetic elements have been made, under special instructions from the Superintendent, at most of the astronomical stations, and near many capes and harbors where a knowledge of the variation of the compass was requisite for the use of navigation. The number of magnetic stations now amounts to about one hundred and sixty, distributed (irregularly as yet) along the entire sea-coast of the United States, on a great portion of which magnetic observations were now made for the first time. The object of this paper is to deduce from the Coast Survey observations, in connection with others of recent date, the general distribution of terrestrial magnetism in the United States, as far as the data available will warrant the conclusions.

These observations have been discussed from time to time under the immediate direction of the Superintendent of the Coast Survey, with the double purpose of determining the distribution of magnetism in different sections of the United States, and the local irregularities. Observations have also been repeated at many places where the discrepancies indicated the necessity for such a course, and generally

resulted in throwing the discrepancies upon the existence of local attraction.

The area under discussion is so large, and the observations comparatively so sparse, that nothing more than the *general* distribution can at present be attempted. Local deviations from the general system, of greater or less magnitude and extent, are apparent in the table of residuals given at the close of this paper, which must be ascribed mainly to local attraction, since the errors of observation are far less in amount, and point out localities where additional observations will be most useful.

The results of the Coast Survey observations are given in Table I., which gives the latitude and longitude of the stations, the declination, dip, and horizontal intensity of the earth's magnetic force, the date of the observations, and a reference to the particular locality, its geology, and other attending circumstances.

The record of these observations, and the details of methods and instrumental constants, will shortly be published as part of the Coast Survey records and results, for the publication of which Congress has provided. A brief notice will therefore suffice here.

In observing the *declination*, the magnetic meridian has generally been obtained by means of collimator magnets, using Gauss and Weber's transportable magnetometer, while the astronomical meridian was derived from the triangle sides of the Coast Survey, or obtained by direct observations.

The *dip* has been observed with needles of from six to ten inches in length, made by Gambey and by Barrow. Two needles have generally been used, — or when one only was employed, it has been carefully tested and compared.

The *horizontal intensity* has been determined in absolute measure by vibrations and deflections, according to the methods of Gauss and Lamont. The units of measure are those used in the British surveys.

From the agreement of repeated observations, it is inferred that the uncertainty of the observations at a particular spot does not exceed one or two minutes of arc in the declination and dip, and $\frac{1}{500}$ part of the horizontal force.

The data derived from other sources that are combined with the Coast Survey observations are all of recent date, in order not to introduce much uncertainty into the reduction to a common period. They are: —

1. Observations by Lieutenant (now Colonel) LEFROY of the R. B. Artillery, in Canada, along the St. Lawrence, and at Toronto; being part of those published by Colonel SABINE in the Philosophical Transactions of 1846 and 1849.

2. Observations made in connection with the Survey of the North-eastern Boundary. — *Ibid.*

3. Observations of Horizontal Intensity in Waterville, Maine. By Professor G. W. KEELY, in 1847, *Philosophical Transactions*, 1848.

4. Observations by the late Dr. JOHN LOCKE, in various parts of the United States, especially in Ohio and the Northwestern States. *American Philosophical Transactions*, 1846, and *Smithsonian Contributions*, 1852. The values of horizontal intensity in this series are originally expressed in terms of the force at Cincinnati, and have been converted into British units through the observations at Toronto, which is one of the stations.

5. Observations in various parts of the Middle and Western States. By Professor E. LOOMIS, *American Philosophical Transactions*, Vols. VII. and VIII.

6. Observations made on the Mexican Boundary Surveys, under the direction of Major W. H. EMORY, U. S. A., recently presented by him to the *American Academy of Sciences.*

7. Observations made by Captain WHIPPLE's party in the Pacific Railroad Explorations near the 35th parallel of latitude. This series, not heretofore published, was kindly furnished us by Captain A. W. WHIPPLE, U. S. Top. Engineers, and is given in full in Table II. It will be seen that a large number of the stations are at a great elevation above the sea level. The effect of elevation on the action of the earth's magnetism has generally been found insensible, and in the absence of any known correction the observations have necessarily been used without regard to height. The observations have been made with a Fox dip-circle, and Cambridge, Mass. was used as reference station for the intensity. The numbers in the table denoting the total intensity may be considered as referring to the arbitrary scale, in which the total force at London is 1.372, with the usual uncertainty on account of secular variation.

For use on the map they have been multiplied by 7.41 to give the total intensity in British units, and by the cosine of the dip for the horizontal force. The factor 7.41 is the ratio of 13.32, the total intensity

in British units at Cambridge, from observations by Mr. W. C. Bond and the Coast Survey observations in the vicinity, to 1.798, the reference number in the table.

8. Table III. gives some observations of declination not before published, collected from various sources for this discussion.

Correction for Secular Variation.

The observations in the discussion have been reduced to the common date of January, 1850, by the best values for the annual change that could be arrived at.

The annual change for the declination and dip has been used as found in the discussion by Mr. C. A. Schott, communicated to the Association by authority of Prof. Bache, and printed in the present volume.

For the Northwestern States we deduce, from scanty data, and have applied, an annual change of from 1′.6 to 2′ decrease of easterly declination.

Determinations of intensity in absolute measure are of so recent a date that but little is known in regard to its secular variation. Observations of the horizontal force at Toronto, Boston, New York, Philadelphia, and Pascagoula, made during the interval between 1843 and 1855, concur in showing a decrease of nearly $\frac{1}{1000}$ part of the force per year. If we suppose the total force to remain constant, the known increase of the dip would account for a rather larger diminution of the horizontal component; and since it is probable that the total intensity is likewise slightly on the increase, the result obtained from our scanty data may be considered sufficiently well established to be used.

Our knowledge of the secular changes on the Western coast and in the Territories is so deficient, that no satisfactory reduction can be applied to the observations. The changes, however, are known to be small, and the observations do not differ greatly in date. Their mean date is about 1852, which may be considered as the period to which the Western part of our map corresponds more nearly than to 1850.

Construction of Map.

In the construction of the lines on the map, both the graphic and analytical methods have been used.

Observations within limited spaces were united into groups, by taking the arithmetical means; a number of such groups were combined

by conditional equations of the second degree, amounting to an interpolation by second differences.

The several systems of groups were so arranged as to overlap, and the slight disagreement in the joining was adjusted by an interpolation partly graphic and partly arithmetical.

When the latitude and longitude of stations have appeared unsuitable co-ordinates of position, owing to the stations being distributed in an oblique direction to the meridian, they were carefully projected on a map and referred by measurement to an assumed axis of co-ordinates in any convenient linear measure; the lines deduced from the conditional equations so formed being projected according to the same system, the latitude and longitude of points in them could be read off and tabulated, the artificial system serving only as a convenient means of interpolation.

On the accompanying maps the lines of equal declination, dip, and horizontal intensity have been drawn only as far as they were warranted by observations. For places within the range of the lines, approximate values may be readily obtained by graphical interpolation.

Table IV. gives the differences between the observed values at the Coast Survey stations reduced to 1850, and the corresponding values on the maps. It will be seen that there are a few large residuals, sometimes exceeding 2° in declination, 1° in dip, and $\frac{1}{20}$ of the horizontal force, which belong to isolated stations (see Mount Pleasant, No. 5, and Patuccawa, No. 15), or very limited localities (see stations near Cape Ann, Nos. 20 to 24); in these cases, local attraction is too apparent to allow the observations to be used in the construction of the map.

We find further, that, in certain more extended localities, the residuals, in declination, amounting in the average to about 20′ or 25′, have one sign, indicating a more general deviation from a regular system. Thus the observed declination near New York, eastward to Black Rock, and westward to Princeton, are larger than those deduced, while near Cape May, in the lower part of New Jersey and Delaware, they are less; in the western part of Massachusetts they are greater, in the eastern part they are less. For the want of more ample material, especially of observations in the interior, no attempt has at present been made to represent these irregularities in the system of lines. They are greatest in amount in the Eastern and Middle States, where

the average of the residuals, irrespective of sign, is 16′, excluding the class first noticed. Along the shores of the Gulf of Mexico it is 6′, and on the Western coast it amounts to 10′.

The residuals of the *dip* observations are less than those of the declination, amounting in the average to 7′, and there are a less number of large disturbances. When we consider that the disturbing polarities probably act nearly in the plane of the horizon, we may conclude that the irregularities of the dip should bear a still smaller proportion to those of the declination; and we see that the constant instrumental errors, which are larger for the dip than for the declination, are not without sensible effect on the magnitude of the residuals.

Upon the same consideration, it will not be surprising that the residuals of the horizontal force observations are larger in proportion than those of the dip, being in the mean about the sixtieth part of the actual values of the horizontal intensities. A variation of 10′ in the dip would correspond to one of the hundred and twentieth part of the horizontal force.

Comparison of Maps.

A comparison of the maps herewith presented with other similar ones that have heretofore been constructed, cannot fail to be interesting and instructive.

Declination. Allowing for the change in ten years, the lines on Professor Loomis's map for 1840 (*Silliman's Journal*, Vol. XL.) agree well with the present map; considering the comparatively small number and often unreliable character of observations they were based upon, the agreement is remarkable, and leads to the hope that valuable results may be derived from the recent observations made in connection with surveys of public lands in the country west of the Mississippi, in which Burts's solar compass has been used to a great extent.

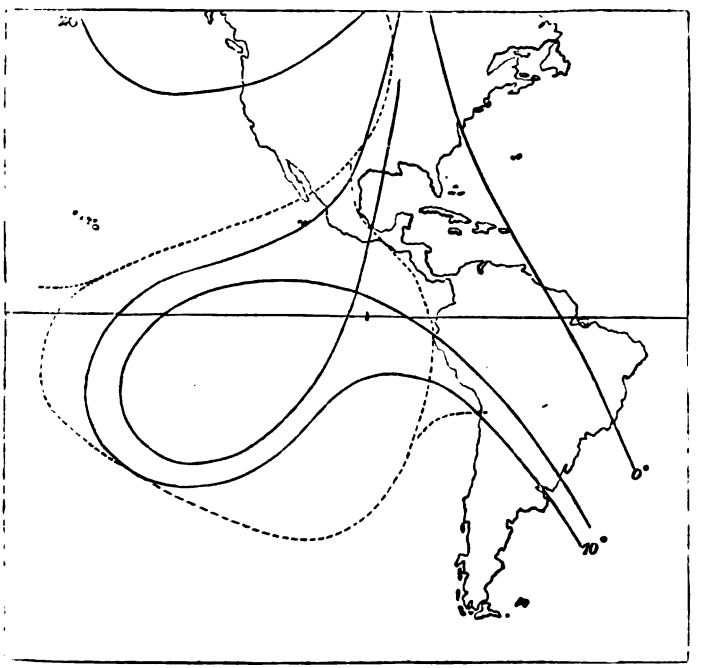
Colonel Sabine's chart of the declination in the Atlantic Ocean (*Philosophical Transactions*, 1849) covers only the northeastern portion of our map, which in that portion in part is based upon the same observations used by him. The agreement is not as close as it would be, if, in reducing the observations of 1844 and 1845 to 1840, the epoch of the map, the secular change used had not been considerably in error, as already noted in Mr. Schott's paper on the secular change of the declination (*Proc. Am. Association, 9th Meeting*). As it is, the

Lith. of J. Bien, 107 Fulton St. N.Y.

lines agree well in direction, but occupy too nearly the same position for the differences of epoch.

The most important comparison is that with Gauss's maps of the computed values of the declination, dip, and horizontal intensity. They are the only ones in which the three elements have been considered as having a necessary connection with each other, and while they may be considerably in error as to absolute quantities, the agreement in *form* with the lines on our maps, derived purely from observations, is strong evidence of the general correctness of the assumptions upon which they are based.

The data for the declination were taken by GAUSS from BARLOW's map in the *Philosophical Transactions*, 1833, of which the mean epoch cannot be later than 1830. The system of lines derived by Gauss on theoretical considerations differs in certain localities materi-



ally from that of Barlow. The annexed diagram exhibits the essential difference in form. While Barlow's line of 10° (indicated by a

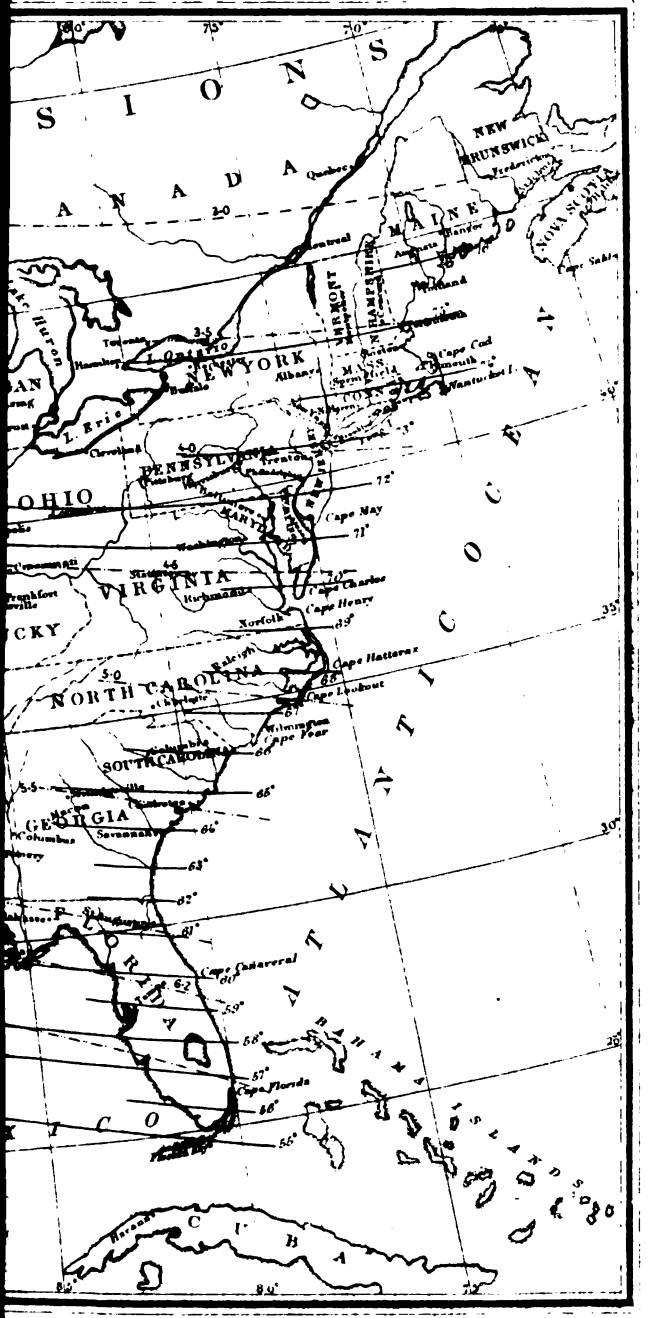
broken line) has several branches which diverge tangentially, according to Gauss such a divergence cannot take place; but when there is a space within which the declination is less than outside any portion of its limiting line, that line must form a loop, the two branches intersecting nearly at right angles, as shown in the looped line of 8° 45′. It must be remembered that the region in question is one where very few observations had been made in 1830, and that Barlow's system is probably quite as much as that of Gauss a theoretical interpolation, though graphically performed; and that hitherto there have been no observed facts, in the region of Texas and New Mexico at least, upon which a decision could be based.

A form of branching similar to that on Barlow's map, and at variance with Gauss's theory, occurs in HANSTEEN'S *Erdmagnetismus*, and has been preserved on a recent map of the declination in his *Magnetiske Inclinations Forandring*, 1855.

It will be seen that, if Barlow's system represents the forms correctly, the line of 9° easterly declination along the coast of Texas should turn to the *southeast*, while the line on our map, fixed by numerous observations, turns decidedly to the *southwest*, in conformity with Gauss's system. In going westward along the Mexican boundary there is not a decrease and subsequent increase, as Barlow's map indicates, but a steady increase, established by the observations along that boundary. The general agreement in form between the lines on our map and the Gauss system is striking. Observations in Central America would at present be of the greatest value in deciding the matter under discussion. The isolated observation at Panama, Table III., has aided greatly in fixing the direction of the line of 7° east, determining that it still turns to the southeast.

On the Atlantic coast the Gauss lines of declination agree well in position with ours, allowing for the difference of epoch. On the western coast they are farther to the south, which seems contrary to what is supposed to be the secular change.

Dip. With LOOMIS'S map before quoted, and SABINE'S map of the dip in British America, *Philosophical Transactions*, 1846, the agreement is excellent. The Gauss lines agree well in form, but differ from 2° to 2½° in the amount of dip. This is due to the errors of Horner's map, from which they are derived, and on which the lines are about 2½° out of position. It must be remembered that they were


S I O N S
A N A D A
NEW BRUNSWICK
MAINE
NEW YORK
MASS.
CONNECTICUT
PENNSYLVANIA
OHIO
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ATLANTIC OCEAN
Quebec
Montreal
Toronto
Albany
Boston
Hartford
Philadelphia
Baltimore
Richmond
Norfolk
Raleigh
Charleston
Savannah
Augusta
Portland
Cape Sable
Cape Cod
Cape May
Cape Charles
Cape Henry
Cape Hatteras
Cape Lookout
Cape Fear
Cape Canaveral
Cape Florida
L. Erie
Havana
C U B A
B A H A M A I S L A N D S
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°

altogether interpolated, no observations of dip in the United States being known when Horner's map was constructed.

Horizontal Intensity. For a comparison of this element, we have only Gauss's chart, on which the lines are affected by the errors of the dip lines, by means of which they have been derived from Sabine's general map of the total intensity for 1836. The values of the Gauss lines being expressed in the arbitrary scale, multiplied by 1000, we reduce them to absolute measure through the observations at Toronto, where in 1844 the total intensity in the arbitrary scale was 1.836, the dip 75° 13′.4, the horizontal force 3.54 in absolute measure in British units, giving a multiplier of 7.56 for the arbitrary scale, or 0.00756 for Gauss's values. We find thus 3.78 equivalent to Gauss's line of 500, along which the actual horizontal force is 4.24 to 4.30; in the same place the dip is really 71° 30′, and on Gauss's map 73° 15′.

Corresponding differences exist in other parts of the map.

Supplementary Note. The following results of observations recently made in Mexico for the Smithsonian Institution are added here, with the permission of the Secretary, from his eleventh report to the Regents. They afford a strong confirmation of the conclusions arrived at in this discussion.

The observations were made under the direction of Baron Mueller, of Marseilles, by Mr. A. Sonntag, during the autumn of 1856, with the modern improved instruments belonging to the Smithsonian Institution.

Name of Station.	Latitude.	Longitude.	Declination East.	Dip.	Horizontal Intensity.
	° ′	° ′	° ′	° ′	
Vera Cruz,	19 12	96 9	8 17	43 58	7.533
Potrero,	18 56	96 48	8 39	42 51	7.576
Orizaba,	18 53	97 4	8 28	42 51	7.579
St. Andrès Chalchecomula,	18 59	97 14	8 13	42 38	7.594
Mirador,	19 13	96 37	8 2	43 48	7.528
City of Mexico,	19 26	99 5	8 46	41 26	7.581

TABLE I. *Magnetic Observations made during the Progress of the*

No	Name of Station.	Latitude.	Longitude.	Declination West.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
1	Mount Harris,	44 39.9	69 8.5	14 34.6	76 14.1	3.236
2	Ragged Mountain,	44 12.7	69 8.7	14 16.8	75 41.2	3.339
3	Camden Village,	44 12.0	69 5.0	13 57.1	75 41.5	3.340
4	Mount Sebattis,	44 9.1	70 4.5	12 53.5	75 40.6	3.411
5	Mount Pleasant,	44 1.6	70 49.0	14 32.1	76 1.5	3.211
6	Cape Small,	43 46.7	69 50.4	12 5.5	75 1.8	3.387
7	Mount Independence,	43 45.5	70 18.9	11 46.4	75 23.8	3.360
8	Burlington,	44 27.5	73 10.0	9 57.1	75 56.8	3.425
9	Bowdoin Hill,	43 38.8	70 16.2	11 41.1	75 14.1	3.450
10	Richmond's Island,	43 32.6	70 14.1	12 18 1	75 8.0	3.463
11	Fletcher's Neck,	43 26 8	70 20.2	11 17.5	75 18.3	3.440
12	Kennebunk Port,	43 21.4	70 27.8	11 23.6	75 14.1	3.448
13	Mount Agamenticus,	43 13.4	70 41.2	10 9 8	74 54.7	3.456
14	Cape Neddick,	43 11.6	70 36.1	11 9.0	74 57.9	3.516
15	Patuccawa,	43 7.2	71 11.5	10 42.8	76 49.5	3.020
16	Kittery Point,	43 4.8	70 42.7	10 30.2	74 57.2	3.500
17	Mount Unkonoonuc,	42 59.0	71 35.0	9 4.1	75 8.7	3.469
18	Isle of Shoals,	42 59.2	70 36.5	10 3.5	74 44.1	3.481
19	Plum Island,	42 48.0	70 48.5	10 5.6	74 54.9	3.530
20	Annis Squam,	42 39.4	70 40.3	11 36.7		
21	Beacon Hill,	42 36.2	70 38.3	11 21.1	74 26 4	3.617
22	Baker's Island Light,	42 32.2	70 46.8	12 17 0	74 18 6	3.674
23	Fort Lee,	42 31.9	70 52.1	10 14.5		3.487
"	" "	" " "	" "	10 49 7	75 36.9	3.489
24	Coddon's Hill,	42 30 9	70 50.9	11 49.8		
25	Little Nahant,	42 26.2	70 55.5	9 40.9	74 29.5	3.555
26	Dorchester Heights,	42 20.0	71 2 2	9 31.4	74 12 7	3.587
	" "	" "	" "	10 13.7	74 29.5	3.544

U. S. Coast Survey, from 1844 *to* 1856, A. D. BACHE, *Superintendent.*

No.	Date.	Locality, Geology, and Remarks.
1	1855.7	Near the geodetic station on the Dixmont Hills, Penobscot Co., Me. Talcose slate of a gray color, running E. N. E. and W. S. W. with a dip to the N. N. W. from 80° to 90°.
2	1854.7	Waldo Co., Me. Gneiss, impregnated with oxide of iron. Near the geodetic station on the summit.
3	1854.8	On Penobscot Bay, Waldo Co., Me. On grounds of Mr. Hugier.
4	1853.6	At the foot of Mt. Sebattis, town of Wales, Me., in the meadow of Colonel H. Marr. On the top of the hill the declination was found to vary from 9° to 14° in a space of 50 yards. The hill is composed of granite with quartz veins and detached masses of mica.
5	1851.6	Town of Denmark, Me. Granite.
6	1851.8	Town of Phippsburg, Me., on the property of Mr. R. Morrison, 50 yards south of geodetic station.
7	1849.8	Town of Falmouth, Me., in a field of Mr. Joseph Hobbes, close to the old road. Drift, clay, and gravel.
8	1855.7	At the flag-staff on Camp ground, city of Burlington, Vt. Drift, clay, and sand 60 or 80 feet deep, overlying limestone and sandstone.
9	1851.6	In the grounds of J. B. Brown, city of Portland. Drift, sand, and gravel.
10	1850.7	In a field near the dwelling-house of Dr. Cummings. Talcose and mica slate, intersected by a large trap dyke.
11	1850.7	Mouth of Saco River, extremity of south point. Metamorphic slate.
12	1851.7	150 yards N. N. W. of Kennebunk Port Observatory. Granite.
13	1847.7	On the summit of Mt. Agamenticus, town of York, Me. Sienite.
14	1851.7	Town of York, Me., in the field of J. Wyer, on the north side of Cape Neddick River, to the south of, and near, the road leading to the sea-shore. Granite underlying the soil.
15	1849.6	On the summit of the hill, in the town of North Deerfield, N. H. Mica slate.
16	1850.7	In an enclosure to the east of R. Gerrish's cottages. Argillaceous slate.
17	1848.8	The highest and most easterly summit of that name in Goffstown, 10 miles west of Manchester. Mica slate.
18	1847.6	On the south side of the harbor of Hog Island, 100 yards from the water. The Isles of Shoals are composed of mica slate and gneiss, with beds of granite ore, and some of them are traversed by dykes of trap.
19	1850.7	Near Thompson's hotel, on Plum Island, near Newburyport, Mass. Drift, covered with sea-sand.
20	1849.7	Sienite. The sienite of the coast of Massachusetts is frequently traversed by dykes of trap, porphyritic trap, &c.
21	1849.7	On the eastern point of Gloucester, Mass. Sienite.
22	1849.7	100 yards from the Light, in the direction of Half-way Rock. Sienite.
23	1849.6	Salem, Mass. Sienite.
"	1855.7	Centre of Old Fort. Granite, partly covered by clay and sand.
24	1849.7	Marblehead, Mass. Sienite.
25	1849.1	On the hill. Sienite.
26	1846.7	On South Boston heights, between Reservoir and Asylum for Blind.
"	1855.7	Drift at least 90 feet deep, clay and sand mixed with pebbles.

No.	Name of Station.	Latitude.	Longitude.	Declination West.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
27	Nantasket,	42 18.2	70 54.0	9 37.4	74 15.9	3.566
28	Blue Hill,	42 12 7	71 6.5	9 13.5	75 5.6	3.519
29	Beacon Pole Hill,	41 59.7	71 26.7	9 27.0	74 21.9	
30	Manomet Hill,	41 55.6	70 35.1	9 16.9	74 30.0	3.640
"	" "	" "	" "		74 1.2	
31	Copecut Hill,	41 43.3	71 3.3	9 8.8	74 9.5	
32	Spencer's Hill,	41 40.7	71 29.3	9 5.9	75 7.1	
33	Shootflying Hill,	41 41.1	70 20.5	9 37.4	74 23.3	3 657
"	" "	" "	" "	9 40.3	73 56.5	3.663
34	Hyannis,	41 37.9	70 18.1	9 21.6	73 49.2	3.682
35	Fairhaven,	41 37.4	70 53.7	8 54.2	74 40.0	3 592
36	Tarpaulin Cove,	41 28.1	70 45.1	9 12.1	73 49 8	3.696
37	Indian Hill,	41 25.7	70 40.3	8 43.9	73 41.4	3.734
"	" "	" "	" "	8 49.4	73 29.1	3.728
38	Sampson's Hill,	41 22.7	70 28.7	8 48.7	73 24.5	3.753
39	Nantucket,	41 17.5	70 5.7	9 14.0	73 44.4	3.653
"	"	" "	" "	9 58.6	74 0 6	3.626
40	McSparran's Hill,	41 29.7	71 27.1	8 48.5	73 47.6	
41	Point Judith Light,	41 21.6	71 28.6	8 59 7	73 45.1	3.788
42	Providence,	41 50.0	71 23 6	9 31.5	74 15.9	3.590
43	Watch Hill,	41 18.8	71 50.9	7 33.4		
44	Stonington,	41 20.0	71 54.0	7 38.1	73 25.0	
45	Groton Point,	41 18.0	72 0.0	7 29.5		
46	Saybrook,	41 16.0	72 20.0	6 49.9	74 33.8	
47	Greenport,	41 6.0	72 21.0	7 14.4	72 57.9	
48	Sachem's Head,	41 17.0	72 43.0	6 15.2		
49	Fort Wooster,	41 16.9	72 53.2	7 27.2	74 16.6	3.667
"	" "	" "	" "	7 25.5	74 12.6	3.609
50	Oyster Point,	41 17.0	72 55.4	6 31.9	73 32.9	3.761
"	" "	41 16.9	72 55.5	7 2.7	73 44.5	3.690
51	New Haven,	41 18.0	72 54.3	6 37 9	73 31.9	3.768
52	Milford,	41 16.0	73 1.0	6 38 3		
53	Bridgeport,	41 10 0	73 11.0	6 19.3	73 21.3	
54	Black Rock,	41 8 6	73 12.6	6 53 5		
55	Norwalk,	41 7.1	73 24.2	6 49.4	73 9.8	
56	Stamford,	41 3.5	73 32 0	6 36 0	73 2.3	3.885
57	Sawpits,	40 59.5	73 39.4	5 58.0	72 53.4	
58	Drowned Meadow,	40 56.1	73 3.5	6 3.6		
59	Lloyd's Harbor,	40 55 6	73 24.8	6 11 6	72 50 6	3.857
60	Oyster Bay,	40 52.3	73 31.3	6 50 5	72 58 8	3.894
61	New Rochelle,	40 52.5	73 47.0	5 29 5	72 44.0	3.845

No.	Date.	Locality, Geology, and Remarks.
27	1847.7	Drift and alluvium, resting on argillaceous slate.
28	1845.8	Dedham, Mass. Sienite.
29	1844.9	Near Cumberland Hill village, R. I. Granite. Iron ore occurs in the neighborhood.
30	1845.7	Near Plymouth, Mass. Drift.
"	1846.7	
31	1844.8	In the town of Fall River, Mass. Granite. Iron ore occurs in the neighborhood.
32	1844.6	Near East Greenwich, R. I. Metamorphic slate of carboniferous age.
33	1845.6	Near Barnstable, Mass. Drift.
"	1846.7	
34	1846 6	On a hill near Hyannis Point, about 60 feet high. Drift.
35	1845.8	Opposite New Bedford, Mass., 22 yards east of fort. Gneiss.
36	1846.6	Nashua, Mass., N. E. of the light, near south shore of the cove. Drift.
37	1845.6	Martha's Vineyard. Tertiary strata.
"	1846.6	
38	1846.6	On Chappaquiddick Island, opposite Edgarton, Martha's Vineyard. Drift.
39	1846.6	On the north beach, near the edge of the town, due N. of Mitchell's Observatory. Drift.
"	1855.6	Argillaceous sand, overlying a stratum of clay, resting on gneiss.
40	1844.6	South Kingston, R. I., in a field near the angle of the roads to Kingston and Wickford.
41	1847.7	100 yards towards Beavertail Light.
42	1855.6	In the rear of Brown University, 198 feet from the central building. Quartz and gneiss rocks, and mica schist.
43	1847.7	Half a mile north of Watch Hill Lights, near Stonington, Conn. Granitic gneiss.
44	1845.6	Connecticut. Reddish granitic gneiss.
45	1845.6	Near New London, Conn. Whitish felspathic gneiss, with mica seams.
46	1845.6	Connecticut. Granitic gneiss.
47	1845.6	In Southold, Long Island. Drift.
48	1845.7	Connecticut. Reddish granitic gneiss.
49	1847.7	Near New Haven, Conn. Trap.
"	1848.7	
50	1848.7	Near New Haven in the meridian of Yale College Observatory. Trap.
"	1855.6	On Howard Avenue, 503 feet from high-water mark on foot of the avenue. Argillaceous soil.
51	1848.6	Near Pavilion Hotel. Sandstone underlying drift.
52	1845.7	Greenstone and chloritic slate.
53	1845.7	Conn. Gneiss and mica slate.
54	1845.7	Conn. Gneiss and mica slate.
55	1844.7	Conn. On Judge Isaac's Hill. Granite.
56	1844.7	Conn. In the rear of the Union Hotel. Granite.
57	1844.7	Steamboat-landing at Port Chester, Westchester Co., N. Y. Gneiss.
58	1845.7	Near Drowned Meadow village, north shore of Long Island. Drift and alluvium.
59	1844.7	Huntingdon, Long Island. Drift, with boulders.
60	1844.7	North shore of Long Island. Drift.
61	1844.7	About 100 yards south of the Neptune House, in New Rochelle, Westchester Co., N. Y. Gneiss and hornblendic rocks.

No.	Name of Station.	Latitude.	Longitude.	Declination West.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
62	Sands' Point,	40 52.0	73 43.0	7 14 6		
"	" "	" "	" "	6 9.9		
63	Legget,	40 48.9	73 53.0	5 41.0	72 52.7	3.976
64	Greenbush,	42 37.5	73 44.0	7 54.7	75 11.1	3.587
65	Cold Spring,	41 25.0	73 57.3	5 34.0	73 54.8	3.790
66	Bloomingdale Asylum,	40 48.8	73 57.4	5 9.7	72 39.0	4.009
67	Columbia College,	40 42.7	74 0.1	6 13.1	72 37.8	
"	" "	" "	" "	6 25.3		
68	Governor's Island,	40 41.5	74 0.8	6 39.6	72 46.3	3.926
69	Bedloe's Island,	40 41.4	74 2.3	7 2.1	72 59.2	3.920
70	Receiving Reservoir,	40 46.7	73 57.8	6 28 0	72 44.4	3.938
71	Newark,	40 44.8	74 7.0	5 35.1	72 52.2	3.964
72	Mount Prospect,	40 40.3	73 57.7	5 54.7	72 27 6	4.053
73	Cole,	40 31.9	74 13.8	5 37.4	72 34.2	4.028
74	Sandy Hook,	40 28.0	73 59.8	5 51.0	72 37.9	4.077
"	" "	40 27.6	73 59.9	6 11.2	72 52.0	3.917
75	Mount Rose,	40 22.2	74 42.9	5 31.8	72 42 5	4.130
76	White Hill,	40 8.3	74 43.6	4 25.9	72 6.2	4.147
77	Vanuxem,	40 6.7	74 52.7	4 27.8	72 22.3	4.068
78	Girard College,	39 58.4	75 9.9	3 51.1	72 1.0	4.143
"	" "	" "	75 9.8	4 31.7	72 17.7	4.226
79	Yard,	39 58.3	75 22.9	6 42.3	73 1.4	3.876
80	Chew,	39 48.2	75 9 7	3 45.2	72 14.4	4.105
81	Tucker's Island,	39 30.8	74 16.9	4 27.8		
82	Tuckerton,	39 36.1	74 19.5		72 12.3	4.063
83	Wilmington,	39 44.9	75 33.6	2 30.7	71 25.4	4.236
84	Sawyer,	39 42.6	75 33.8	2 48.3	71 57.5	4.175
85	Church Landing,	39 40.6	75 30.4	5 49.1	71 22.0	4.311
86	Fort Delaware,	39 35.3	75 33.8	3 16.8	71 34.9	4.226

No.	Date.	Locality, Geology, and Remarks.
62	1845.7	40 yards E. N. E. from Sands' Point Light. Drift covered with alluvium.
"	1847.8	Near the Light-House.
63	1847.8	In a cove north of Rikers' Island, Long Island Sound. Gneiss covered with alluvium.
64	1855.7	Opposite Albany, N. Y., near Second Street, east of the Hudson River Railroad track. Clayey sand and dark-blue marl.
65	1855.7	Near the Hudson River, opposite West Point, on a bluff close to the village. Granite.
66	1846.3	Manhattan Island. Gneiss rock, underlying the soil.
67	1844.7	City of New York. Gneiss rock underlying drift, loam, and gravel.
"	1845.7	City of New York.
68	1855.6	New York harbor, between Fort Columbus and Castle William, in range with Trinity Church steeple and Battery flagstaff. Quartzose sand, overlying mica schist and granite.
69	1855.6	New York harbor, north side of Island, to the northward of the flagstaff. Quartzose sand, overlying metamorphic rock.
70	1855.6	City of New York, inside the Receiving Reservoir, near corner of 79th Street and 7th Avenue. Gneiss.
71	1846.4	New Jersey. Alluvial soil, sand, and gravel, superimposed on secondary red sandstone in place.
72	1846.3	Near Brooklyn, Long Island. Drift, with small boulders of granite and trap.
73	1846.4	In Westfield, southwestern part of Staten Island. Drift, with small boulders.
74	1844.6	250 yards north of Light. Green-sand formation; alluvial sand.
"	1855.6	About 250 feet west of the Light-House on the top of a dune. The Hook consists of downs, and the quartz sand was found 25 feet deep.
75	1852.6	About 5 miles west of Princeton, N. J., in a field near the house of Thomas Hunt. Trap rock protruding through secondary red sandstone.
76	1846.4	Near Bordentown, N. J., on the bank of the Delaware River. Cretaceous marl.
77	1846.5	At Professor Vanuxem's, two miles above Bristol, on the Delaware River, 100 yards N. W. of the canal. Sand, clay, and gravel superimposed on metamorphic rock.
78	1846.4	In the yard of the Magnetic Observatory at Girard College, Philadelphia.
"	1855.7	To the northward and eastward of the College, within the enclosure, and in the road in the rear of the smaller building next to the College. Metamorphic rock, below gravel, etc.
79	1854.8	About 10 miles west of Philadelphia 250 yards E. S. E. of the trigonometrical station.
80	1846.5	Near Woodbury, N. J. Marl and green-sand of cretaceous formation.
81	1846.9	Entrance to Little Egg Harbor, N. J., N. W. point of island. Alluvium and white sand.
82	1846.9	
83	1846.4	Delaware. A hill 1¼ miles W. N. W. of the Town-Hall. Trap, covered with red clay. Local attraction.
84	1846.4	3 miles south of Wilmington, Del. At the edge of the tertiary formation no rocks or boulders apparent.
85	1846.4	New Jersey, on Delaware River. Drift. Local attraction ascertained to exist by partial observations at these localities.
86	1846.5	Pea-patch Island, Delaware River. Alluvial mud at least 70 feet deep.

No.	Name of Station.	Latitude.	Longitude.	Declination West.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
87	Hawkins,	39 25.6	75 17.0	2 58 8	71 42.6	4.224
88	Pine Mount,	39 25.0	75 19.9	3 14.2	71 41.4	4.237
89	Bombay Hook Light,	39 21.8	75 30.3	3 18.5	71 39.5	4.201
90	Port Norris,	39 14.6	75 1.0	3 4.4	71 39.6	4.211
91	Egg Island Light,	39 10.5	75 8.0	3 3.0	71 45.1	4.206
92	Town Bank,	38 58.6	74 57.4	2 59.0	71 23.6	4.269
93	Cape May Light (old),	38 55.8	74 57.6	3 5.1	71 25.8	4.255
"	" " " (new),	" "	74 57.4	3 45.4	71 34.4	4.182
94	Lewes's Landing,	38 48.8	75 11.5	2 45.0		
95	Pilot Town,	38 47.1	75 9.2	2 42.7	71 18.5	4.290
96	Osborne's Ruin,	39 27.9	76 16.6	2 32.4	71 47.6	4.143
97	Susquehanna Light,	39 32.4	76 4.8	2 13.7	71 52.1	4.086
98	Finlay,	39 24.4	76 31.2	2 14.6	71 52.9	4.059
"	"	" "	" "	2 18.5	71 45.2	4.170
99	Pool's Island,	39 17.1	76 15.5	2 29.3	71 52.1	4.117
100	Rosanne,	39 17.5	76 42.8	2 10.9	72 6.6	4.053
101	Fort McHenry,	39 15.7	76 34.5	2 18.6		
102	North Point,	39 11.7	76 26.3	1 36.7	71 29.5	4.183
"	" "	" "	" "	1 39.6		
103	Bodkin Light,	39 8.0	76 25.2	2 1.9	71 43.1	4.189
104	Kent Island, (1)	39 1.8	76 18.8	2 30.2	71 16.6	4.208
105	South Base, Kent Island,	38 53.8	76 21.7	2 24.3	71 37.0	4.206
106	Taylor,	38 59.8	76 27.6	2 14.4	71 40.2	4.231
"	"	" "	" "	2 18.0	71 19 3	4.221
107	Marriott,	38 52.4	76 36.2	2 9.4	71 10.9	4.260
"	"	" "	" "	2 5.0	71 13.0	4.228
108	Webb's Hill,	39 5.3	76 40.2	2 7.9	71 24.0	4.279
109	Soper's Hill,	39 5.1	76 56.7	2 7.1	71 56.5	4.142
110	Hill's Hill,	38 53.9	76 52.5	2 18.6	71 12.2	4.316
111	Causten's Hill,	38 55.5	77 4.1	1 11.3	71 18.9	4.229
"	" "	" "	" "	1 6.2	71 30.2	4.250
"	" "	" "	" "	1 6.0		
112	Washington City,	38 53.2	77 1.2	5 44.2	71 27.0	4.337

No.	Date.	Locality, Geology, and Remarks.
87	1846.5	Near Roadstown, N. J. Cretaceous formation. Some ferruginous sandstone in vicinity.
88	1846.5	An isolated hill near Greenwich, N. J. Cretaceous; unmagnetic iron ore.
89	1846.5	About 60 miles E. S. E. of the Light-House. Alluvial clay and sand.
90	1846.5	New Jersey. Cretaceous marl and sand.
91	1846.5	Delaware Bay, 60 yards S. by W. of Light-House. Cretaceous marl and sand.
92	1846.5	At Price's, near Cape May. Cretaceous marl and sand.
93	1846.5	70 yards S. E. of Light-House. Cretaceous marl and sand.
"	1855.6	About 160 yards W. of the Light-House, near the sand dunes. Quartz, sand, and broken shells.
94	1846.5	Near Cape Henlopen.
95	1846.5	On Cape Henlopen. Clay and sand.
96	1845.5	Near Abingdon, Md. Talcose slate and hornblende.
97	1847.5	A short distance to the N. W. of Light-House, at the mouth of Susquehanna River. Ferruginous clay and sand.
98	1845.5	On Cub Hill, the property of J. B. Finlay, 9 miles north of Baltimore, on the Harford Turnpike. Metamorphic rocks underlying gravel and sand.
"	1846.3	
99	1847.5	Chesapeake Bay, near the dwelling of P. Wethered, on the upper island. Alluvial clay and sand.
100	1845.4	On Prospect Hill, 5 miles from Baltimore, north of the old Frederick road. Alluvial clay and sand.
101	1847.3	Baltimore harbor; between the Hospital and western stable. Ferruginous sand and clay.
102	1846.5	Between the two Lights at the mouth of the Patapsco River. Ferruginous sand and clay.
"	1847.3	
103	1847.3	20 yards S. S. E. from Light-House. Ferruginous sand and clay.
104	1849.5	North end of Kent Island, Chesapeake Bay. Ferruginous sand and clay.
105	1845.4	On the west shore of Kent Island, opposite Thomas's Point, 21 yards north of monument. Ferruginous sand and clay.
106	1845.4	On the north side of Severn River, opposite Annapolis, Md. Ferruginous sand and clay.
"	1847.4	
107	1846.4	A prominent hill near West River, Md., the property of Bushrod Marriott. Green-sand formation, ferruginous clay and marl.
"	1849.5	
108	1850.9	Anne Arundel Co., Md., near the Annapolis Railroad, 12 miles from Annapolis. Green-sand formation, ferruginous clay and marl.
109	1850.6	Prince George's Co., Md., 14 miles from Washington City, on the old Columbia road, property of J. B. Downs. Talcose slate.
110	1850.7	Prince George's Co., Md., 6 miles east of Washington City. Ferruginous clay and sand.
111	1851.5	Near Georgetown, D. C., 122 yards west of the geodetic station, in the grounds of J. H. Causten. Mica slate, with quartz veins, underlying ferruginous clay and gravel.
"	1855.7	At the geodetic station, 1° 10′.3, in September, and 1° 2′.0 in October, by two different instruments.
"	1855.8	Same station as in June, 1851.
112	1855.6	Near Magnetic Observatory, in the Smithsonian grounds. Affected by local attraction changing within the enclosure as much as 1½° Declination; on Capitol Hill, near Gilliss' station, by compass needle, 2° 25′. Ferruginous clay and sand overlying mica schist.

No.	Name of Station.	Latitude.	Longitude.	Declination West.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
113	Davis,	38 20.4	75 6.0	2 33.0	70 57.7	4.332
114	Roslyn,	37 14.4	77 23.6	0 26.5	69 17.3	4.614
115	Stevenson's Point,	36 6.3	76 10.7	1 39.6	68 54.5	4.660
116	Shellbank,	36 3.3	75 43.8	1 44.8	68 37.8	4.714
117	Bodie's Island,	35 47.5	75 31.6	1 13.4	68 18.1	4.755
				D. East.		
118	Raleigh,	35 46.8	78 37.8	0 44.5	68 11.6	4.943
119	De Rosset,	34 14.0	77 56.5	1 13.5	66 47.2	5.174
120	Columbia,	34 0.0	81 2.0	3 1.7	66 7.7	5.274
121	Allston,	33 21.7	79 12 3	2 6.5	65 29.5	5.402
122	Macon,	32 50.4	83 37 6	4 36.4	63 51.0	5.637
123	Breach Inlet,	32 46.3	79 48.7	2 16.5	64 31.9	5.457
124	East Base, Edisto Island,	32 33.3	80 10 0	2 53.6	64 4.1	5.532
125	Savannah,	32 5.0	81 5.2	3 40.3	63 40.0	5.600
126	Tybee Island,	32 1.5	80 50 6	3 32.1	63 38.4	5.584
127	Cape Florida,	25 40.4	80 9.8	4 25.2	56 13.0	6.615
128	Sand Key,	24 27.2	81 52.7	5 28.8	54 25.8	6.758
129	Depot Key,	29 7.5	83 2.8	5 20.5	59 55.3	6.140
130	St. Mark's Light,	30 4.5	84 12.5	5 29.2		
131	Dog Island,	29 47.1	84 36.0	5 51.2		
132	St. George's Island,	29 37.4	85 1.1	6 2.1		
133	Cape St. Blas,	29 39.6	85 23.9	6 6.5		
134	Hurricane Island,	30 4.4	85 40.3	6 12.2		
135	Fort Morgan,	30 13.9	88 0.3	7 4.1		6.218
136	East Pascagoula,	30 20.7	88 31 8	7 12.6	60 27.2	6.220
"	" "	" "	" "	7 8.9		6.174
137	Montgomery,	32 22.0	86 18.0	5 18.3	63 5.4	5.850
138	Fort Livingston,	29 16.7	89 48.5	7 38.4		
139	Isle Dernière,	29 2.0	90 54.3	8 19.2		
140	Dollar Point,	29 26.0	94 52.6	8 57.4	57 53.3	6.541
141	East Base,	29 12.9	94 55.4	9 5.0	57 42.1	6.491
142	Jupiter,	28 54.8	95 20.1	9 8.7	57 11.7	6.582
143	Rio Grande,	25 57.4	97 7.6	9 0.9	52 23.6	
144	San Diego,	32 42.0	117 13.3	12 28.8		
"	" "	" "	" "	12 31.7	57.38.6	6.271

No.	Date.	Locality, Geology, and Remarks.
113	1853.7	On the west shore of Sinepuxent Bay, east of Berlin, Md. Ferruginous clay, and sand.
114	1852.6	Near Petersburg, Va. Drift, ferruginous clay.
115	1847.1	Western Point, at the mouth of Little River, Albemarle Sound, N. C. Tertiary clay and sand.
116	1847.3	On Albemarle Sound, east point of entrance into Currituck Sound. Alluvial mud, sand, and shells.
117	1846.9	North Carolina, near the beach, about 5 miles N. N. W. of the Light-House. White sand.
118	1854.0	North Carolina. Station 105 feet east, and 26 feet north of centre of Capitol dome. Granite rock underlying the soil.
119	1854.4	On a lot adjoining Dr. Drane's residence, north side of Market Street, Wilmington, N. C. Tertiary clay, gravel, and sand.
120	1854.2	South Carolina. In the Capitol Square, near the southwestern corner.
121	1853.9	Near Georgetown, S. C. Alluvium.
122	1855.0	Georgia.
123	1849.3	On Sullivan's Island, Charleston entrance, South Carolina. White sand.
124	1850.3	Edisto Island, S. C. Tertiary formation, alluvial mud, clay, and sand.
125	1852 3	On Hutchinson's Island, in range of Exchange and Presbyterian Church steeples, near the second embankment from the river. Alluvium.
126	1852.3	Near the mouth of Savannah River on a sand dune, near the boat-house.
127	1850.1	On the inside beach of Key Biscayne, the Light-House bearing S. W. Black mud and white sand.
128	1849.6	Near Key West, Florida. A small island on Florida Reef, composed of detritus of marine shells and coral.
129	1852.2	Cedar Keys, Fla., on the highest point of the island. Drifted white sand on alluvial mud.
130	1852.3	In the salt marsh, about 400 yards north of the Light.
131	1853.3	Apalachicola entrance (eastern). White sea-sand.
132	1853.3	Near Cape St. George, west entrance to Apalachicola Bay, Fla. White sea-sand.
133	1854.1	Florida. White sea-sand.
134	1854.1	St. Andrew's Bay, Fla. White sea-sand.
135	1847.4	400 yards N. E. of the N. W. bastion of Ft. Morgan, Mobile Pt., Ala. Drifted white sand.
136	1847.5	Mississippi. About 1 mile east of the mouth of Pascagoula River, in the village near the shore. Tertiary formation, ferruginous clay and white sand. Dip observed in 1848.
"	1855.1	
137	1855.3	Near N. E. corner of Capitol Square. Deep red clay.
138	1853.0	Barataria Bay, La. Alluvium covered with drifted white sand.
139	1853.1	Caillou Bay, La. Alluvium covered with drifted white sand.
140	1848.3	On Galveston Bay, 10 miles N. W. of Galveston, Texas. Sandy loam.
141	1853.2	On Galveston Island, 10 miles S. W. of Galveston, and half a mile from the Gulf shore. Sandy loam.
142	1853.4	Four miles S. W. of Quintana, Texas, near the beach. Drifted sand.
143	1853.9	Near the mouth, on the American side. Alluvium.
144	1851.3	California, at the Plaza, near the "quarters." Very coarse sandstone. The high ridge of Point Loma is to the west.
"	1853.8	At the Plaza, near the Custom-House.

No.	Name of Station.	Latitude.	Longitude	Declination East.	Dip.	Horizontal Intensity.
		° ′	° ′	° ′	° ′	
145	San Pedro,	33 46.0	118 16.0	13 30.5	59 32.6	6.144
146	Point Conception,	34 26.9	120 25.6	13 50.2		
147	San Luis Obispo,	35 10.6	120 43.5	14 16.9	59 42.2	6.002
148	Point Pinos,	36 38.0	121 54.4	14 58.3		
149	San Francisco,	37 47.6	122 26.8	15 26.9		
150	Bucksport,	40 46.6	124 10.7	17 6.5		
151	Humboldt,	40 44.7	124 11.0	17 4.5		
152	Ewing Harbor,	42 44.4	124 28.8	18 29.7		
153	Cape Disappointment,	46 16.6	124 2.0	20 19.1		
154	" "	" "	" "	20 45 3		
155	Scarborough Harbor,	48 21.8	124 37.2	21 29.9		
156	Waddah Island, Neé-ah Bay,	48 22.0	124 36.6	21 46.9	71 7.0	4.276

No.	Date.	Locality, Geology, and Remarks.
145	1853.9	On the open plain, about 3 miles north of San Pedro. Gravel resting on beds of recent fossil shells.
146	1850.7	Near the mouth of the valley of El Coxo. A rich soil; surrounding hills show limestone, quartz, &c.
147	1854.1	The surrounding hills are of soft limestone, resting on coarse, red sandstone, bearing enormous fossil remains, probably of tertiary age.
148	1851.1	Near Monterey, Cal. A rich soil, resting on sandstone. Beach formed of large granite boulders.
149	1852.2	Near the Presidio. Surrounding hills limestone.
150	1853.6	On the beach; sand and marsh.
151	1854.3	At the foot of the western part of the Bluff, composed of ferruginous clay and sand, resting on gravel, bearing fossil remains of *Elephas primigenius*.
152	1851.9	Near Cape Orford, Oregon. Geology very varied. South of Port Orford, coal and plumbago. North, limestone filled with fossil shells.
153	1851.5	On the beach; white sand, mixed with black ferruginous and auriferous sand. Surrounding hills basalt.
154	1851.5	On the summit of the Cape. Horizontal columnar basalt.
155	1852.6	Near Cape Flattery, Washington Territory. Sand, surrounding hills varied, limestone principally; basalt cropping out at Tootash Island.
156	1855.6	Near Cape Flattery, Washington Territory. Sandstone and shales of coal measures.

TABLE II.

Magnetic Observations made on the Pacific Railroad Exploration, near the Parallel of 35°. By LIEUTENANT J. C. IVES, *under the Direction of* CAPTAIN A. W. WHIPPLE, *U. S. Top. Engineers.*

No.	Date.	Name of Place.	Latitude.	Longitude.	Elevation.	Declination.	Dip.	Total Intensity. Arb. Scale.
			° ′	° ′	Feet.	°	° ′	
1	Aug. 9, 1850,	Cambridge Observatory,	42 23	71 7		W. 9 30	74 34	1.798
1	May 10, 1854,	Cambridge Observatory,	42 23	71 7		9 46	74 33	1.798
2	Oct. 17, 1853,	Albuquerque,	35 6	106 38	5026	E. 13 25	62 28	1.689
3	Nov. 9, "	Isleta,	34 54	106 40	4910	13 13	62 24	1.686
4	" 12, "	Rio San José,	35 1	107 14	5556	13 4	63 18	1.689
5	" 14, "	Covèro,	35 5	107 26	5880	13 49	62 26	1.689
6	" 15, "	Hay Camp,*	35 5	107 39	6081	35 56	35 39	1.566
7	" 17, "	Aqua Fria,	35 2	107 58	7757	13 25	62 5	1.687
8	" 18, "	Prescription Rock,†	35 3	107 14	7238	12 57	62 3	1.679
9	" 22, "	Zuñi River,	35 6	108 39	6336	13 24	62 2	1.683
10	" 26, "	Arch Spring,	35 5	108 48	6350		61 55	1.682
11	" 28, "	Cedar Forrest,	35 1	108 55	6162	13 1	61 40	1.679
12	" 29, "	Jacob's Well,	35 4	109 14	5973	13 44	61 59	1.674
13	" 30, "	Navajo Spring,	35 6	109 20	5665	13 23	61 58	1.675
14	Dec. 1, "	Carriso Creek,	35 6	109 32	5550	13 54	62 5	1.673
15	" 2, "	Near Lithodendron Creek,	35 2	109 41	5500	13 33	61 57	1.667
16	" 3, "	Near Rio Puerco of West,	34 58	109 52	5110	14 0	61 46	1.668
17	" 5, "	Color. Chiq., or Flax Riv.,	34 53	110 4	5015	13 42	62 15	1.670
18	" 7, "	On Colorado Chiquito,	35 0	110 25	4735	13 40	61 54	1.665
19	" 8, "	" " "	35 1	110 30	4760	13 21	61 41	1.663
20	" 15, "	" " "	35 5	110 33	4675		61 44	1.662
21	" 16, "	" " "	35 12	110 37	4618	13 39	61 45	1.668
22	" 17, "	" " "	35 18	110 53	4594	13 42	61 55	1.667
23	" 18, "	" " "	35 21	110 56	4570		62 3	1.678
24	" 29, "	Saroux Spring,	35 17	111 39	7378	13 52	61 33	1.659
25	Jan. 9, 1854,	Cedar Creek,	35 21	112 29	5672	13 49	62 6	1.674
26	" 21, "	Pueblo Creek,	34 56	112 46	5203	13 59	61 13	1.652
27	" 23, "	Williams River,‡	34 59	112 57	5752	14 48	61 6	1.648
28	" 28, "	" "	35 7	113 13	4680	13 40	61 17	1.618
29	" 30, "	Head of White Cliff Creek,	35 12	113 21	4784		61 14	1.659
30	Feb. 1, "	White Cliff Creek,	35 8	113 31	3526	14 42	60 48	1.648
31	" 4, "	Big Horse Springs,	35 1	113 36	2784	14 18	61 2	1.631
32	" 8, "		34 36	113 28	1657	14 02	60 36	1.622
33	" 9, "	Williams River,	34 32	113 28	1500	13 58	60 44	1.627
34	" 13, "	" "	34 17	113 26	1015	13 24	60 14	1.631
35	" 15, "	" "	34 13	113 33	899	13 41	60 8	1.629
36	" 16, "		34 14	113 39	868		60 10	1.624
37	" 20, "		34 17	113 56	441		60 11	1.623
38	" 21, "	On Colorado River,	34 23	114 6	382	14 8	60 34	1.626
39	" 22, "		34 27	114 11	416		60 35	1.628
40	" 23, "		34 36	114 16	590	13 51	60 30	1.627
41	" 25, "		34 46	114 23	432	13 36	60 48	1.629
42	Mar. 1, "		34 52	114 32	430	13 56	60 57	1.635
43	" 3, "	Pai-ute Creek,	35 6	114 54	2790	14 17	61 10	1.635
44	" 6, "	Near Marl Springs,	35 11	115 33	3793	13 59	60 56	1.627
45	" 7, "	Sand Camp,	35 6	115 46	2038		60 49	1.632
46	" 8, "	Soda Lake,	35 3	115 59	1002	13 51	61 7	1.633

* This camp was upon the south side of the stream of lava which threads the valley of the Rio San José.

† This station was under the northern bluff of El Moro.

‡ Much lava in the vicinity of this station.

TABLE III.

Magnetic Observations from various Sources, not heretofore published, and collected for this Discussion.

Name of Place.	Latitude.	Longitude.	Declination.	Date.	Authority.
	° ′	° ′	° ′		
Heiner's Run, N. Br. Susq., Pa.,	41 20	77 50	3 19 W.	1856	S. Tyndale.
Kelly's Island, west end L. Erie,	41 36	82 43	2 13 E.	1846	Maps of Lakes Surveys by U.S. Top. Engineers.
East Sister Island, " " "	41 49	82 51	2 18 "	1847	
West Sister " " " "	41 44	83 6	2 20 "	"	
Stony Point, " " "	41 56	83 15	2 7 "	1848	
Waugoshance Pt., Mackinac Str.,	45 45	84 56	2 13 "	1853	
East of Duncan City, " "	45 36	84 7	1 53 "	1851	
Near Newport, Franklin Co., Mo.,	38 30	91 10	9 21.6 "	1839	Dr. Goebel.
" " " "	" "	" "	9 5.4 "	1849	" "
Fort Union,	48 0	103 59	16 48 "	1853	Gov. I. I. Stevens.
Fort Benton,	47 52	110 36	19 0 "	"	Northern Pacific Railroad Explorations.
Fort Owen,	46 31	113 58	19 25 "	"	
Fort Wallawalla,	46 4	118 48	19 40 "	"	
Panama, New Grenada,	8 57	79 29	6 54.6 "	1849	Mex. Boun. Sur.

TABLE IV.

Residual Differences between the Coast Survey Observations, reduced to 1850, *and the Values obtained from the Accompanying Maps.*

The sign + or — shows how the residual is to be applied to the observed value to give that on the map.

No.	Station.	Declination.		Dip.		Horisontal Intensity.	
		° ′	° ′	° ′	° ′		
1	Mount Harris,	+14 6	— 6	76 2	+ 4	3.28	— .04
2	Ragged Mountain,	13 54	— 27	75 32	+ 13	3.37	— .06
3	Camden Village,	13 36	— 8	75 32	+ 12	3.37	— .05
4	Mount Sebattis,	12 35	— 6	75 35	+ 8	3.43	— .09
5	Mount Pleasant,	14 24	—2 48	75 59	— 20	3.22	+ .15
6	Cape Small,	11 57	+ 19	74 58	+ 32	3.40	— .01
7	Mount Independence,	11 45	— 3	75 24	+ 3	3.36	+ .05
8	Burlington,	9 29	+ 1	75 44	+ 10	3.46	— .11
9	Bowdoin Hill,	11 32	+ 9	75 11	+ 10	3.46	— .03
10	Richmond Island,	12 15	— 40	75 7	+ 8	3.46	— .01
11	Fletcher's Neck,	11 14	+ 10	75 17	+ 1	3.44	+ .02
12	Kennebunk Port,	11 15	— 6	75 11	— 2	3.46	+ .02
13	Mount Agamenticus,	10 21	+ 30	74 57	+ 6	3.45	+ .05
14	Cape Neddick,	11 0	— 1	74 55	+ 8	3.53	— .03
15	Patuccawa,	10 45	— 27	76 50	—1 50	3.02	+ .51
16	Kittery Point,	10 27	+ 15	74 56	+ 4	3.50	+ .02
17	Mount Unkonoonuc,	9 10	+ 37	75 10	— 19	3.47	+ .09
18	Isle of Shoals,	10 15	+ 26	74 46	+ 8	3.47	+ .07
19	Plum Island,	10 2	+ 19	74 53	— 8	3.53	+ .04
20	Annis Squam,	11 39	—1 21				
21	Beacon Hill,	11 23	—1 5	74 27	+ 9	3.62	— .02
22	Baker's Island Light,	12 18	—2 18	74 19	+ 14	3.69	— .08
23	Fort Lee,	10 16	— 16				
"	" "	10 21	— 21	75 26	— 53	3.53	+ .08
24	Coddon's Hill,	11 51	—1 48				
25	Little Nahant,	9 43	+ 8	74 30	— 3	3.55	+ .09
26	Dorchester Heights,	9 48	— 9	74 16	+ 5	3.58	+ .07
"	" "	9 45	— 6	74 18	— 3	3.57	+ .08
27	Nantasket,	9 49	— 4	74 18	+ 2	3.56	+ .09
28	Blue Hill,	9 35	— 5	75 10	— 52	3.50	+ .17
29	Beacon Pole Hill,	9 53	— 50	74 27	— 18		
30	Manomet Hill,	9 38	+ 10	74 34	— 27	3.62	+ .09
				74 4	+ 3		
31	Copecut Hill,	9 35	— 29	74 14	— 20		
32	Spencer's Hill,	9 32	— 41	75 13	—1 20		
33	Shootflying Hill,	9 58	— 16	74 28	— 34	3.64	+ .10
"	" "	9 57	— 15	74 0	— 6	3.65	+ .09
34	Hyannis,	9 39	+ 4	73 51	0	3.67	+ .07
35	Fairhaven,	9 15	— 9	74 44	— 55	3.57	+ .19
36	Tarpaulin Cove,	9 17	— 17	73 53	— 10	3.68	+ .10
37	Indian Hill,	9 6	+ 7	73 46	— 5	3.71	+ .08
"	" "	9 6	+ 7	73 32	+ 9	3.71	+ .08
38	Sampson's Hill,	9 6	+ 15	73 28	+ 11	3.74	+ .05
39	Nantucket,	9 31	+ 2	73 49	— 12	3.64	+ .14
"	"	9 31	+ 2	73 49	— 12	3.66	+ .16
40	MacSparran's Hill,	9 16	— 25	73 53	— 10		
41	Point Judith Light,	9 11	— 41	73 47	— 10	3.78	+ .02
42	Providence,	9 2	— 5	74 5	— 2	3.63	+ .11
43	Watch Hill,	7 45	+ 30				
44	Stonington,	8 0	+ 9	73 30	+ 8		

No.	Station.	Declination.		Dip.		Horizontal Intensity.	
		° ′	° ′	° ′	° ′		
45	Groton Point,	+7 51	+ 10				
46	Saybrook,	7 12	+ 30	74 40	—1 9		
47	Greenport,	7 37	— 4	73 2	+ 22		
48	Sachem's Head,	6 37	+ 44				
49	Fort Wooster,	7 39	— 30	74 19	— 49	3.66	+ .21
"	" "	7 32	— 23	74 14	— 44	3.60	+ .27
50	Oyster Point,	6 38	+ 28	73 34	— 4	3.76	+ .11
"	" "	6 35	+ 31	73 33	— 3	3.73	+ .14
51	New Haven,	6 42	+ 27	73 33	— 2	3.78	+ .08
52	Milford,	7 0	+ 3				
53	Bridgeport,	6 41	+ 10	73 26	— 2		
54	Black Rock,	7 15	— 33				
55	Norwalk,	7 16	— 43	73 11	+ 6		
56	Stamford,	7 2	— 41	73 8	+ 11	3.86	+ .06
57	Saw-Pits,	6 24	— 12	72 59	+ 15		
58	Drowned Meadow,	6 25	+ 23				
59	Lloyd's Harbor,	6 38	— 14	72 56	+ 16	3.84	+ .10
60	Oyster Bay,	7 17	—1 2	73 4	+ 3	3.87	+ .08
61	New Rochelle,	5 56	+ 1	72 49	+ 18	3.82	+ .14
62	Sands' Point,	7 36	—1 33				
"	" "	6 21	— 18				
63	Legget,	5 52	— 7	72 55	+ 10	3.97	.00
64	Greenbush,	7 26	— 2	74 59	— 26	3.63	+ .03
65	Cold Spring,	5 5	+1 10	73 43	— 5	3.83	+ .03
66	Bloomingdale Asylum,	5 28	+ 20	72 43	+ 25	4.00	— .02
67	Columbia College, N. Y.,	6 40	—1 11	72 43	+ 14		
"	" "	6 47	—1 4				
68	Governor's Island,	6 11	— 38	72 35	+ 20	3.97	+ .03
69	Bedloe's Island,	6 34	—1 4	72 48	+ 6	3.96	+ .05
70	Receiving Reservoir,	6 0	— 15	72 33	— 31	3.98	— .04
71	Newark,	5 53	— 20	72 56	— 4	3.95	+ .03
72	Mount Prospect,	6 13	— 31	72 31	+ 29	4.04	— .06
73	Cole,	5 55	— 34	72 38	+ 9	4.02	+ .01
74	Sandy Hook,	6 13	— 43	72 43	+ 2	4.05	+ .01
"	" "	5 43	+ 13	72 41	+ 4	3.96	+ .08
75	Mount Rose,	5 19	— 31	72 37	— 0	4.15	— .09
76	White Hill,	4 44	— 5	72 7	+ 17	4.14	— .04
77	Vanuxem,	4 45	— 15	72 26	+ 2	4.06	+ .05
78	Girard College,	4 9	— 0	72 5	+ 11	4.13	+ .01
"	" "	4 3	+ 6	72 6	+ 10	4.27	— .13
79	Yard,	6 18	—2 21	72 52	— 36	3.91	+ .23
80	Chew,	4 3		72 18	— 11	4.09	+ .07
81	Tucker's Island,	4 43	— 4				
82	Tuckerton,			72 26	— 26		
83	Wilmington,	2 49	+ 50	71 29	+ 35	4.22	— .04
84	Sawyer,	3 6	+ 33	72 1	— 1	4.16	+ .03
85	Church Landing,	6 7	—2 25	71 26	+ 31	4.30	— .10
86	Fort Delaware,	3 35	— 2	71 38	+ 14	4.22	— .01
87	Hawkins,	3 16	+ 26	71 46	— 1	4.21	+ .02
88	Pine Mount,	3 32	+ 7	71 45	— 1	4.23	+ .01
89	Bombay Hook Light,	3 36	— 6	71 43	— 3	4.19	+ .06
90	Port Norris,	3 22	+ 29	71 43	— 6	4.20	+ .05
91	Egg Island Light,	3 20	+ 22	71 49	— 17	4.20	+ .06
92	Town Bank,	3 16	+ 29	71 27	— 8	4.26	+ .03
93	Cape May Light (old),	3 23	+ 19	71 29	— 7	4.24	+ .06
"	" " " (new),	3 17	+ 25	71 23	— 1	4.22	+ .08
94	Lewes's Landing,	3 1	+ 23				

No.	Station.	Declination.		Dip.		Horizontal Intensity.	
		° ′	° ′	° ′	° ′		
95	Pilot Town,	+3 0	+ 27	71 22	— 11	4.28	+ .06
96	Osborne's Ruin,	2 55	— 4	71 52	— 10	4.12	+ .13
97	Susquehanna Light,	2 26	+ 37	71 55	— 7	4.08	+ .16
98	Finlay,	2 37	— 4	71 57	— 19	4.04	+ .22
"	"	2 37	— 4	71 49	— 1	4.16	+ .10
99	Pool's Island,	2 42	+ 3	71 55	— 18	4.11	+ .17
100	Rosanne,	2 34	— 13	72 11	— 37	4.03	+ .26
101	Fort McHenry,	2 32	— 2				
102	North Point,	1 57	+ 43	71 33	— 4	4.17	+ .13
"	" "	1 53	+ 40				
103	Bodkin Light,	2 19	+ 14	71 46	— 17	4.18	+ .12
104	Kent Island, (1)	2 33	+ 6	71 17	+ 5	4.21	+ .11
105	South Base, Kent Island,	2 47	— 20	71 41	— 29	4.19	+ .16
106	Taylor,	2 37	— 13	71 45	— 26	4.21	+ .12
"	"	2 31	— 17	71 22	— 3	4.21	+ .12
107	Marriott,	2 27	— 15	71 14	— 5	4.25	+ .11
"	"	2 7	+ 15	71 13	— 4	4.23	+ .13
108	Webb's Hill,	2 3	+ 15	71 22	+ 2	4.29	+ .03
109	Soper's Hill,	2 4	— 1	71 55	— 31	4.14	+ .19
110	Hill's Hill,	2 15	— 15	71 11	+ 1	4.31	+ .05
111	Causten's Hill,	1 4	+ 44	71 16	— 4	4.23	+ .13
"	" "	38	+1 10	71 19	— 7	4.28	+ .08
"	" "	37	+1 11				
112	Washington City,	5 38	—3 47	71 16	— 6	4 38	— .01
113	Davis,	2 14	+1 1	70 50	— 2	4.35	+ .06
114	Roslyn,	13	+ 32	69 12	+ 21	4.64	+ .02
115	Stevenson's Point,	1 53	— 44	68 58	— 22	4.65	+ .14
116	Shellbank,	1 57	— 27	68 40	— 4	4.70	+ .09
117	Bodies Island,	+1 27	+ 3	68 21	+ 3	4.74	+ .08
118	Raleigh, N. C.,	—1 3	+ 11	68 4	— 7	4.97	— .03
119	De Rosset,	1 30	+ 27	66 38	— 6	5.20	— .04
120	Columbia, S. C.,	3 18	+ 12	66 0	— 9	5.30	
121	Allston,	2 22	+ 10	65 22	+ 7	5.43	— .08
122	Macon, Ga.,	4 30	+ 30	63 41	+ 28	5.67	+ .01
123	Breach Inlet,	2 14	— 34	64 32	+ 14	5.46	
124	East Base, Edisto Island,	2 54	— 9	64 4	+ 23	5.53	
125	Savannah,	3 49	+ 10	63 35	+ 13	5.62	
126	Tybee Island,	3 41	+ 8	63 34	+ 14	5.60	+ .03
127	Cape Florida,	4 25	— 8	56 13	+ 8	6.61	— .09
128	Sand Key,	5 29	+ 5	54 26	+ 1	6.76	+ .07
129	Depot Key,	5 22	+ 12	59 55	+ 8	6.15	+ .04
130	St. Mark's Light,	5 31	+ 1				
131	Dog Island,	5 53	+ 10				
132	St. George's Island,	6 4	+ 10				
133	Cape St. Blas,	6 8	+ 4				
134	Hurricane Island,	6 14	+ 6				
135	Fort Morgan,	7 3	— 1			6.21	
136	East Pascagoula,	7 12	0	60 30	— 3	6.20	
"	" "	7 12	0			6.20	
137	Montgomery,	5 6	—1 4	62 52	+ 20	5.89	— .10
138	Fort Livingston, Belle Isle,	7 40	— 4				
139	Isle Dernière,	8 20	+ 17				
140	Dollar Point,	8 57	— 7	57 53	+ 7	6.53	— .04
141	East Base,	9 7	— 4	57 42	3	6.52	+ .02
142	Jupiter,	9 10	— 5	57 12	6	6.59	
143	Rio Grande,	—9 2	— 5	52 23	7		

No.	Station.	Declination.		Dip.		Horizontal Intensity.	
		° ′	° ′	° ′	° ′		
144	San Diego,	—12 28	— 21				
"	" "	12 32	— 25	57 38	+ 33	6.30	— .04
145	San Pedro,	13 37	+ 18	59 32	— .17	6.17	— .01
146	Point Conception,	13 50	+ 5				
147	San Luis Obispo,	14 13	+ 6	59 42	+ 45	6.03	— .03
148	Point Pinos,	14 57	— 0				
149	San Francisco,	15 25	— 10				
150	Bucksport,	17 3	— 14				
151	Humboldt,	17 0	— 16				
152	Ewing Harbor,	18 28	+ 6				
153	Cape Disappointment,	20 19	+ 22				
154	" "	20 45	— 4				
155	Scarborough Harbor,	21 27	— 7				
156	Waddah Isl. (Neé-ah Bay),	—21 41	+ 8	71 7		4.32	.00

V. METEOROLOGY.

1. On the Spirality of Motion in Whirlwinds and Tornadoes. By W. C. Redfield, of New York.

1. An aggregated spiral movement, around a smaller axial space, constitutes the essential portion of whirlwinds and tornadoes.

2. The course of the spiral rotation, whether to the right or left, is one and the same in this respect, throughout the entire whirling body, so long as its integrity is preserved. But the oblique inclination which the spiral movement also has to the plane of the horizon, is in opposite directions as regards the exterior and interior portions of the revolving mass. Thus, in the more outward portion of the whirlwind, the tendency of this movement is obliquely downward, when the axis is vertical; but in the interior portion, the inclination or tendency of the spiral movement is upward. This fact explains the ascensive effects which are observed in tornadoes and in more diminutive whirlwinds.

3. Owing to the increased pressure of the circumjacent air, in approaching the earth's surface, the normal course of the gradually descending movement in a symmetric whirlwind is that of an invo-

luted or closing spiral; while the course of the interior *ascending* movement of rotation is that of an evolved or opening spiral. Hence, the horizontal areas of the higher portions of the whirl exceed greatly those of its lower portions.

4. The area of the ascending spiral movement in the vortex, as it leaves the earth's surface, is by far the smallest portion of the whirling body; for the reason that the rotation here is proportionally more active and intense, being impelled by the aggregated pressure and momentum of the more outward portion of the whirlwind as it converges from its larger areas, on all sides, by increasingly rapid motion, into the smaller areas of ascending rotation.* That this interior portion of the whirl resembles an inverted hollow cone, or column, with quiescent and more rarefied air at its absolute centre, may be inferred from the observations which have been made in the axial portions of the great cyclones. Into this axial area of the tornado the bodies forced upward by the vortex cannot fall, but are discharged outwardly from the ascending whirl. The columnar profile of this axial area sometimes becomes visible, as in the water-spouts, so called.

5. Accessions caused by circumjacent contact and pressure are constantly accruing to the whirling body, so long as its rotative energy is maintained. A correlative diffusion from its ascending portion must necessarily take place, towards its upper horizon; and this is often manifested by the great extent or accumulation of cloud which results in this manner from the action of the tornado. In other words, there is a constant discharge from the whirling body in the direction of least resistance.

6. The spirality of the rotation, and its inclination to the horizon, in

* The law of increment in the velocity of the whirlwind, as it gradually converges into lesser areas by its spiral involution, is that which pertains to all bodies when revolving around interior foci towards which they are being gradually drawn or pressed nearer and nearer, in their involute course; the line of focal or centripetal pressure thus sweeping *equal areas in equal times*, at whatever diminution of distance from the centre; except as the velocity may be affected in degree by the resistance of other bodies. Such resistance is of little effect in a tornado, because its revolving mass is mainly above all ordinary obstacles, such as orchards and forests, into which the spirally *descending* and accelerated blast, near the contracted extremity of the inverted and truncated cone of the whirl, penetrates with constant freshness and intensity of force, already acquired in the higher and unobstructed region.

the great portion of the whirl which is exterior to its ascending area, are not ordinarily subject to direct observation. Nor is the outline or body of the more outward portion of the whirlwind at all visible, otherwise than in its effects.

7. In *aqueous* vortices, the axial spiralities of the exterior and interior portions of the whirl are in reverse direction to those in the atmosphere, the descending spiral being nearest to the axis of the vortex. Hence, lighter bodies, and even bubbles of air, are often forced downward in the water, in the manner in which heavier bodies are forced upward in the atmosphere.

The foregoing is simply a statement of results which I have derived from a long course of observation and inquiry. It does not include the partial and imperfect exhibitions of whirlwind action, which often occur, nor the various movements and phenomena which are collaterally associated with tornadoes and whirlwinds, some of which are of much significance.

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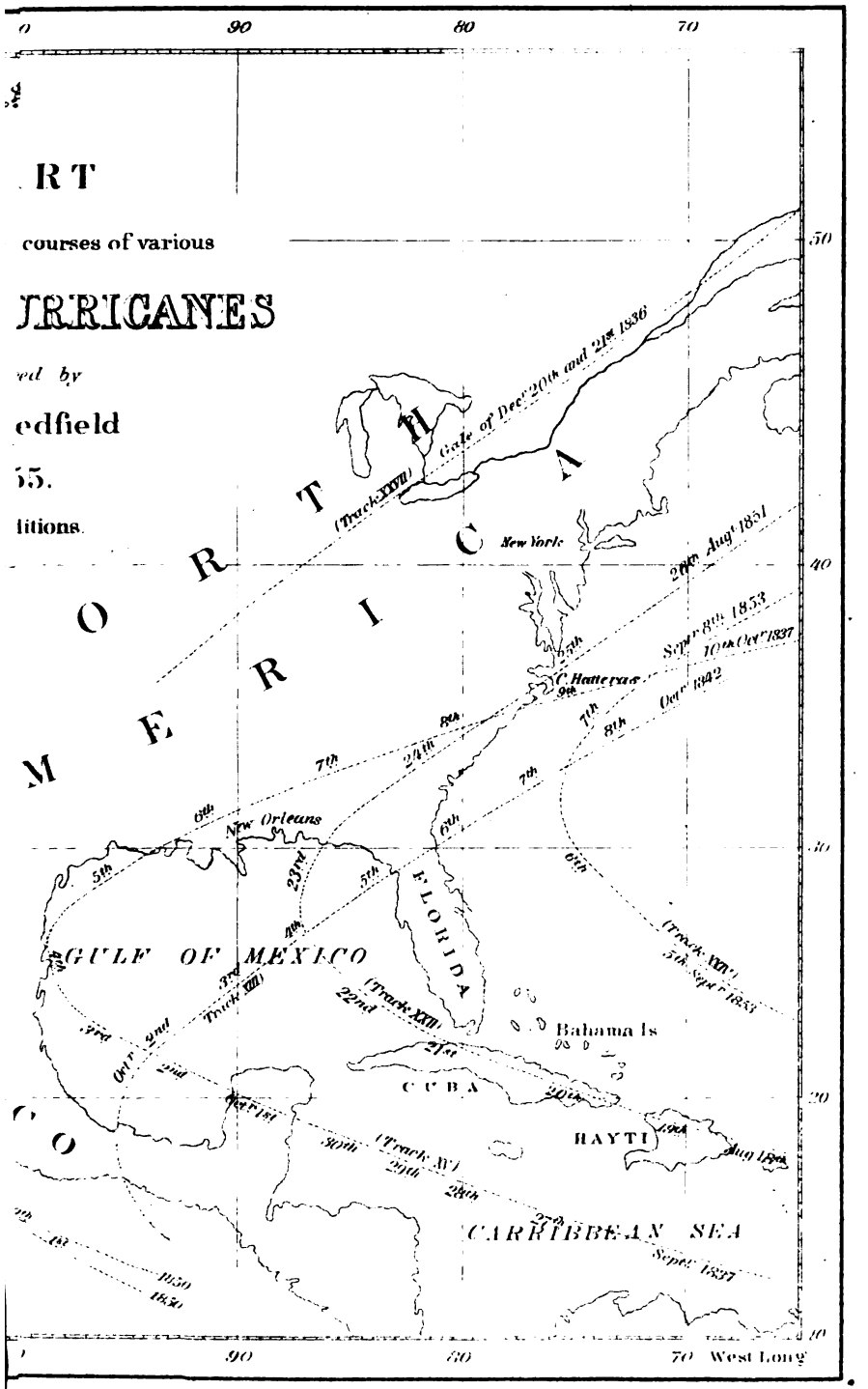
2. On Various Cyclones or Typhoons of the North Pacific Ocean; with a Chart, showing their Courses of Progression. By W. C. Redfield, of New York.

This memoir is founded to a considerable extent on data obtained from the log-books and meteorological reports of the ships composing the Expedition to Japan, under the command of Commodore Matthew C. Perry, and is intended for publication in the appendix to the official account of the Expedition.

Of the typhoon encountered by the United States ship Mississippi, on the 7th of October, 1854, on her return from Japan, some notice was given at the last meeting of the Association at Providence. Allusion was then made, also, to the great cyclone encountered by various ships of the squadron, in July, 1853, between the coasts of China and Japan, and at the Loo Choo Islands. This remarkable storm spread over a path of perhaps one thousand miles in breadth, while its rate of advance hardly exceeded three miles an hour.

The Chart then exhibited, on which were shown the courses of


RT
courses of various
JRRICANES
ed by
edfield
55.
litions.
O R T H A
M E R I C
Gale of Dec^r 20th and 21st 1836
(Track XXVII)
New York
24th Aug^t 1851
Sept^r 8th 1853
10th Oct^r 1837
C. Hatteras
Oct^r 1842
New Orleans
FLORIDA
GULF OF MEXICO
(Track XXVI)
5th Sept^r 1837
Bahama Is
CUBA
HAYTI
CARRIBBEAN SEA
Sept^r 1837
1850
1851
90
80
70
West Long^e
50
40
30
20
10

several cyclones in the North Pacific, has been improved by various additions, and is now offered for publication. Some portions of the memoir, with several abbreviated reports of cyclones, are here submitted.

CYCLONES AND THE MONSOONS. — In the Asiatic seas, as elsewhere, the judgment of the navigator is often misguided by the loose and inaccurate statements which are found in various authorities. Thus, it is said that gales or hurricanes rarely occur in these seas, except at the change of the monsoons, or the period of the equinoxes. These assumed axioms are greatly erroneous; as the inspection of the storm charts will suffice to show.

The actual relations of the cyclones to the monsoons and local winds of the Asiatic seas are of much interest, and merit a careful examination. It is quite remarkable that the monsoons should be found to have little, if any, control or influence, as regards the regular courses and development of the cyclones. This may show the predominance of cosmical laws and influences over the apparently opposing conditions which are so extensively presented in these alternating winds.

The extent of the westerly monsoons, parallel to, and on both sides of, the equator, appears to be far greater than has been recognized by most writers. In the northern hemisphere, these counter winds of the true trades extend from the east coast of Africa, near longitude 45° E., at least to longitude 175° E., in the Central Pacific. The proper trade-wind appears to consist of a comparatively thin stratum of aerial current, moving upon the ocean surface, and distinguished by its inclination towards the equator. On this stratum is ordinarily imposed another current, probably of greater depth and volume, into which the trade-wind ultimately merges, and which also tends westward in the trade-wind latitudes, but generally inclines *from* the equator; as is shown by the rain-clouds and squalls which it carries, and by the direction of translation imparted to the cyclones which it embodies. This important wind-current, so little recognized by most writers, frequently alternates with or displaces the true trades, and it displaces still more frequently the westerly monsoon, as a surface wind; especially to the east of Sumatra. Thus, the "southwest monsoon" of the China Sea and the Western Pacific, which extends to the shores of Japan, is very often displaced from the surface by the subsidence

of the main current of southeasterly wind; more especially in the regions near the Asiatic coast.

UNIVERSALITY OF THE LAW OF STORMS. — The law of rotation and progression in storms, as developed on the Atlantic Ocean, which was substantially discerned by the present writer in the year 1821, is essentially cosmical or world-wide in its origin and application. This soon became apparent, in examining the accounts of gales which are found in the voyages of Cook, Vancouver, and others, in the several oceans and climatory zones of our globe. Hence, the polar relations of the phenomena presented are necessarily changed in the southern hemisphere, where, in all our relative comparisons, south must be substituted for north; east and west remaining the same.

This similarity of polar relations in the winds of the two hemispheres, and the corresponding influences on the barometer which are shown by the opposite cyclonic changes of these winds, are virtually recognized in Captain P. P. King's account of his surveying expedition in the southern hemisphere, about the year 1826, as is seen in his sailing directions. The more complete and satisfactory evidence of this cosmical system, or law, of cyclonic action, which is derived from a series of extensive geographical observations, made in the paths of storms in the southern hemisphere, has since been furnished in the several works of Reid, Thom, and Piddington. The latter author has also investigated many storms of the Sea of Bengal and the Indian Ocean, and has noticed various gales or typhoons of the China Sea. Some of the following notices may serve to increase our knowledge of Asiatic storms.

CHINA SEA AND GULF OF TONQUIN. — On the southern coast of China, the semiannual changes of the monsoons are found to occur in April, and about the end of September. On former occasions I have published notices of some of the numerous typhoons which cross the China Sea, more commonly from May to October, on routes corresponding in direction to those of the hurricanes in the West Indies, and with like characteristics. That observant old voyager, Dampier, states that on the coast of Tonquin the typhoons are expected in the months of July, August, and September. He says, that in these typhoons "the wind comes on fierce, and blows very violent at north-

east, twelve hours, more or less. When the wind begins to abate, it dies away suddenly, and falling flat calm, it continues so an hour, more or less; when the wind comes about to the southwest, and it blows and rains as fierce from thence as it did before from the northeast, and as long." A better description of a violent cyclone, as observed on its centre-path in the lower latitudes, and before its recurvation, could hardly be given.

A Typhoon in February, in the Trade-Winds of the Pacific. — At noon of February 3d, 1853, the Annie Buckman, sailing for Canton, was in latitude 12° 30′ N., longitude 129° 16′ E., with barometer at 29.75, and a double-reefed topsail breeze from northeast. Between this time and the 9th the vessel was subject to a very violent typhoon; during which both the direction of the wind and the course of the vessel went round the compass, by the north, west, and south, to the northeast quarter, on the 9th. At noon of this day the vessel was in latitude 18° 9′ N., longitude 127° 25′ E., barometer 29.80, and of the few entries given, the lowest was 29.25, at 4 P. M. of February 7th; wind then from the westward, and increasing soon after to its greatest violence. Captain Barber states that in twenty years of navigation, in all oceans, he had not encountered ahurricane so violent.

Bonin Islands. — On the 25th of October, 1853, the United States ship Plymouth encountered a typhoon at Port Lloyd, in latitude 27° 5′ N., longitude 142° 11′ E., which commenced with squalls of wind from east-southeast, under which the barometer began to fall. "At 9 P. M. it fell calm, and continued so for little less than an hour, when the wind came out again suddenly from northwest, with terrific violence, blowing, if anything, still harder than from east-southeast. Barometer when lowest, 28.97; at which it arrived very rapidly; and when it commenced rising, it did so in the same manner." This cyclone evidently completed its recurvation while passing over the Bonin Islands.

On the 28th of October, 1854, another severe typhoon passed over Port Lloyd, where the United States ship Vincennes, of the surveying expedition, was then lying at anchor. In its recurvation, its centre went round to the westward of Port Lloyd, as indicated by the suc-

cessive phases of the wind and barometer. It has been ably described by John Rodgers, Esq., commander of the expedition, and Anton Schönborn, assistant astronomer, in a communication addressed to the present writer.

REINDEER'S CYCLONE, JULY, 1850. — The American ship Reindeer was dismasted in a furious hurricane on the 19th of July, 1850, in latitude 18° 30′ N., longitude 139° E.; about twelve hundred miles from the coast of China. She ran with bare poles, under the easterly winds of the cyclone; thus nearing its vortex, till the barometer had fallen to 28.85, when the wind veered to south-southeast, in a perfect blast; the ship broached to, and the masts soon went overboard.

With the knowledge of storms we now possess, our ships ought not to be thus disabled in open sea.

THE FREAK'S TYPHOON OF MAY 1, 1850. — The English brig Freak fell in with this cyclone in latitude 19° 28′ N., longitude 138° 44′ E., with the wind east by south, varying to east by north, and the brig ran westward with an increasing gale. At midnight the master began to suspect that he was approaching the vortex of a cyclone that was travelling to the northwest, and at 1 A. M., May 2d, he hove to on the starboard tack, to allow it to pass him. It continued blowing a hurricane, and at noon the wind became east-northeast, with the barometer at 29.22. Between 2 and 3 P. M., the foretopmast was broken off by the force of the wind, which at this time was beyond description. At 3.50 P. M., the barometer had fallen to 28.87, its lowest point. The wind from noon continued to haul northward, its greatest strength being from about northeast by north, and the master thus found, to his surprise, that he was in the northwest quadrant of the cyclone, and on the left side of its centre path; it having already recurved to the northward and eastward. From 4 P. M., the barometer began to rise, and the force of the gale to decrease.

The easterly winds of this cyclone having veered by the north, the master's inference that the recurvation in its course took place during the time his vessel was in the gale, appears correct; the centre of the vortex having recurved southward and eastward of the vessel's place. His full account may be seen in the London Nautical Magazine, 1851, pp. 273 – 275.

LADRONE OR MARIAN ISLANDS. — These islands lie near longitude 146° E., and are subject to hurricanes, for which the inhabitants prepare, by lashing down and securing their houses. They are expected in the months of June, July, and August; also, in December and January. The island of Guam, latitude 13° 26′ N., was visited on the 23d of September, 1855, by a typhoon of the most violent character. More than eight thousand persons were left without a house or roof to protect them from the fury of the storm.

CYCLONE OF THE J. N. GOSLER, MAY, 1855. — The American ship J. N. Gosler, from San Francisco for Hong Kong, experienced a heavy typhoon on the 28th of May, 1855, in latitude 16° 40′ N., longitude 147° 45′ E.; nearly two thousand miles from the Chinese coast. She carried away sails, spars, &c., and was abandoned on the 30th, with nine feet of water in the hold. The officers and crew succeeded in reaching the Marian Islands, in their boats.

STRONG'S ISLAND AND ASCENSION. — Mr. John T. Gulick, of the Sandwich Islands, in the year 1852, visited several of the Micronesian Islands, near the equator, in company with the missionaries who then settled at these islands. At Strong's Island (Nalan), in latitude 5° 12′ N., longitude 163° E., they were informed by King George, the principal chief, that some years previous the island had been visited by a hurricane which wholly destroyed the bread-fruit trees, and caused a famine which nearly depopulated the island. He described it as blowing first from one quarter of the heavens and then from another. At Ascension Island (Bonabe), which is about three hundred miles distant in a west-northwest direction, a similar account was received.

CYCLONE OF THE AUSTERLITZ, NOVEMBER, 1851. — The new clipper Witchcraft arrived at Hong Kong on the 3d of December, from California, with loss of mainmast-head and all the topmasts. She experienced a typhoon on the 13–14th of November, in latitude 22° 40′ N., longitude 150° E.

About the same period, in latitude 19° 48′ N., longitude 159° E., the American ship Austerlitz was totally dismasted. The chain-plates were torn from her sides, and her hull otherwise much injured, and the vessel was soon after abandoned.

It cannot be doubted that the Austerlitz and Witchcraft fell, successively, into the heart of this cyclone. We have thus two points established in its track, which are distant from each other about five hundred and thirty nautical miles. These positions show its course to have been north 71° west, or west-northwest, nearly. The position of the Austerlitz is more than two thousand five hundred miles from Hong Kong, and is somewhat less from the Sandwich Islands.

KINGSMILL ISLANDS AND GILBERT ARCHIPELAGO. — These islands, situated on and near the equator, near longitude 175° E., were visited by a ship of the United States Exploring Expedition under Captain Wilkes. Variable winds from the northward and westward prevail from October to April; and they have violent gales from the southwest. According to Kirby, who was taken off the islands, these storms are typhoon-like, and last three or four days. The westerly sides of the islands receive most damage, and both land and trees are swept away.

RADACK ISLANDS. — These islands are scattered between 6° and 11° north latitude, and longitude 168° to 173° E. Captain Kotzebec ascertained that hurricanes of great violence sometimes occur in September and October, and the natives always anticipate with dread the recurrence of those months.

THE JAPAN'S TYPHOON. — In December, 1832, the Japan, a new ship, encountered a severe hurricane in latitude 13° N., longitude about 160° W. This position is nearly on the meridian of the most western of the Sandwich Islands.

THE SANDWICH ISLANDS. — At the Sandwich Islands, latitude 19° to 22° N., longitude 155° to 160° W., the cyclones which occur are not commonly of great severity, although the native huts are sometimes unroofed or destroyed. The *kona*, or southerly wind, by which the trade-wind, during part of the year, is much interrupted, may be referred, at least in part, to those cyclones which find their centre-path northward of the islands, or which complete their recurvation in that region. The easterly gales, which accord nearly with the trade-wind in their direction, indicate an axis-path which lies southward of the islands. The actual presence or influence of a cyclone may commonly be determined by the oscillations of the barometer.

The absence of intense violence in any of the cyclones which visit this group may possibly be due to their geographical position. But it is equally probable that this qualified exemption may result from a diversion of the course of the central vortex of the cyclone, occasioned by the great height and compact form of Hawaii, the most southeastern of these islands. For the group lies in almost a direct line, which is parallel to the ordinary course of cyclones in the lower latitudes, being, from the summit of Mauna Kea to the centre of Kauai, north 61° west. A cyclonic vortex, if moving previously on this line, would be displaced by the eastern angle of Hawaii; which island has an area of nearly four thousand square miles; a portion of which rises far above the upper horizon of the cyclones, and at two points reaches an elevation of nearly fourteen thousand feet. The protection, or partial diversion of course thus occasioned, must extend to the high but smaller islands which lie to the leeward in the same track.

Cyclone of the Lark. — The Lark, an American barque from Canton for Valparaiso, met a severe gale on the 23d of September, 1843, in latitude 15° N., longitude 138° 40′ W. The Lark also encountered a violent typhoon at an earlier date, when off the island of Formosa.

Cyclones of the Eastern Pacific. — For the sake of brevity, I pass over several accounts of violent cyclones which have been found between the Sandwich Islands and the Southern coasts of Mexico and Central America. The occurrence of hurricanes in this part of the Pacific is by no means unfrequent; and the cases I have quoted are instructive to navigators. The omitted notices are contained in the appendix to the account of the Japan Expedition, already referred to. The sketches of storm-tracks, as first intimated, are found on the small chart of the North Pacific, hereto appended.

If these imperfect notices shall contribute in any degree to the safety and success of our ships and commerce, it will be a grateful reward for the attention and labor which this important subject has at any time required.

New York, *September 6th*, 1856.

3. On the Avoidance of the Violent Portions of Cyclones, with Notices of a Typhoon at the Bonin Islands. By John Rodgers, Commander, U. S. N., and Anton Schönborn, Assistant Astronomer. (In the form of Letters to W. C. Redfield, by whom they were communicated to the Association.)

Commander Rodgers's Letter.

I am a firm believer, out of my own experience, in the truth of your theory of hurricanes. I think you have enabled me to avoid storms, into whose centres I should have been unwilling to be involved, and I feel, therefore, that I am under personal obligations to you for your happy meteorological discoveries. You have conferred by them a great good to the nation and to the world.

I do not know whether my notes of weather have any value in regard to the hurricane experienced by the Mississippi, on October 7th, 1854. On September 23d, preceding this typhoon, we were in the China Sea, in latitude 21° 44′ N., longitude 119° 17′ E. The weather was very threatening. We were standing to the southward, and a black cloud was ahead of us, with vivid lightning, with a cross and violent sea, with heavy rain, and fitful squalls continually increasing in frequency and force. I considered that I saw a cyclone before us, and that we should avoid its force, by sailing away from it. We stood to the northward. The barometer soon rose, and the wind moderated.

At the Bonin Islands, on October 28th, 1854, we had a typhoon. The harbor of Port Lloyd is formed by the crater of an extinct volcano. The sides rise precipitately above the water to the height of some twelve hundred feet. You will easily perceive, then, that the anchorage must be in a great degree protected from the violence of the wind. Yet it blew awfully. It stripped all the leaves from the trees, all vegetation was blighted, and even the sweet-potato vines in the sheltered valleys were destroyed by it. As I could not at first believe that the wind had destroyed them, I attributed their wilting and turning black to some unseen electrical agency. I afterwards concluded that the wind had twisted and torn their sap-vessels, so as to destroy their vitality.

This storm was not so marked as to give any distinct warning of its

approach. The evening before the hurricane, the surf broke more heavily upon the mouth of the harbor than I had seen it. Had we been at sea, I have little doubt but that we should have known of its approach. This storm is well described in the accompanying paper by Mr. Schönborn, assistant astronomer on board.

We had a gale on November 9th, 1854, in latitude 18° 22′ N., longitude 143° 45′ E., which I thought was the edge of a typhoon. We ran on until I had satisfied myself as to its character, and then we hove the ship to on the starboard tack, heading away from it. We soon raised the barometer and improved the weather. This case is also described in the accompanying paper of Mr. Schönborn.

In the steamer John Hancock, which I commanded, we were, on May 20th, 1854, upon the verge of a typhoon. The weather was not violent, but the seas were peculiar, rising up into sharp cones, and running in every direction. They buffeted the vessel in every part, — striking her upon the lee bow and weather quarter at once. I remarked to the officers on board, that I felt sure we were upon the edge of a typhoon. It gave me, however, no uneasiness. I concluded that we were behind it, and that keeping the vessel away would increase our distance from it.

We steered off once, in a fresh squall, for about fifteen minutes, and then hauled up to our course again. We ran on with a fair wind. I expressed a wish to know how any vessel some one or two hundred miles to the northward and eastward of us was faring.

This curiosity was satisfied by the accompanying extract from the log-book of the British ship, Harkura. She was a large Indiaman, well out of the water, and in appearance such a strong, wholesome vessel as a seaman would select to stand heavy weather.*

Typhoons are rare in the China seas in the month of May. This is therefore not without interest.

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* The ship Harkura left Hong Kong for London, May 16th, 1854, and returned to port, under jury masts, on the 11th of June. She had fine weather till the 18th, on which day boarded the Dutch barque Johan Paul, then just escaped from pirates. On the 19th, wind fresh and steady at east and east-northeast. On the afternoon of 20th [*nautical time*] moderate winds from east-northeast, the barometer falling in the evening, with lightning to the southward. Latitude at noon of that day, 16° 22′ N., longitude 113° E. At 10 P. M., a heavy bank rising in the southeast, with lightning and distant thunder, close-reefed the topsails and stowed the mainsail,

Anton Schönborn's Letter.

During the past five days the weather had been rather warm, but very fine. Light winds from southeast were prevailing, which kept

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spanker, and jib. At midnight, barometer still falling, took in mizzen-topsail and foresail, and at 2 A. M. stowed main-topsail. Not much wind, but sea getting cross and high. At 5 A. M., strong winds and heavy rain, barometer fallen three tenths since the preceding noon. Sent down all top hamper, and secured all sails with extra gaskets. At 10 A. M. [Saturday, 20th] gale increased to a hurricane, with a fearful cross, high sea. Stowed fore-topsail and topmast-staysail, and brought the ship to on port tack, got a sail in mizzen-rigging to keep ship to the wind, then so violent that no sail could stand it. At noon [commencement of 21st, nautical time] latitude, by account, 15° N., longitude 112° 20′ E.

The afternoon commenced with a severe gale, speedily increasing to a perfect hurricane; barometer down to 28.50. At 2 P. M. ship lying with her lee yard-arms in the water, and barometer still falling rapidly. Fearing the ship would founder, cut away fore and mizzen-topmasts; but that being insufficient to right the vessel, cut away the fore-topmast. The vessel then righted a little, the wind still blowing with fearful violence, and increasing. The main-topmast went over the side, taking with it the head of the mainmast.

Immediately after this it fell a flat calm; the barometer down to 27.70. Got the wreck of main-topmast cut away from alongside, as well as that of the foremast, which hung to windward. At 3 P. M., the wind blew to the northwest, veering to west and southwest, blowing with tenfold violence. The lee bulwarks all gone, with everything movable about the deck, the sea up to the combings of the main hatch. The starboard side of forecastle washed out, and also starboard poop cabin. At 3.45 P. M., ship righting a little, rigged two pumps and pumped her dry. At 6 P. M., the fury of the typhoon moderated, and the barometer commenced rising. Gale continued at southwest, veering round to south. Commenced rigging jury-masts. May 22d [nautical time], latitude 15° N., longitude 112° 10′ E. At 8 P. M. [21st, true time] weather moderated. Sea going down and barometer rising. Wind south and southeast. — *Extracted from Hong Kong Gazette, June 14th, 1854.*

Captain Crowe's Remarks on the above Typhoon. — The evening of Friday, May 19th, the weather looked very threatening, but nothing gave reason for suspecting the vicinity of a typhoon. [?] The clouds had a dirty, red appearance; but the quickly repeated flashes of lightning and the distant moaning of the thunder in the southeast quarter were portentous of an approaching gale. The barometer did not give early indications of what was coming, [?] only three tenths of fall appearing up to the time of the commencement of the gale. The fall then, however, was very rapid, and in all of twenty years' experience (eleven in command) I never saw the mercury so low in the tube by an inch. During the lull, when we were in

the temperature of the air, even in the night, above 80°, yet in the warmest hours of the day it would seldom be over 85° in the shade. This morning, before sunrise, light squalls from southeast, accompanied by drizzling rain, interrupted for the first time the continued fine weather we had experienced. At noon the wind changed to the north of east, the rain ceased, it began to clear up, and I could see the blue

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the vortex, the barometer, a standard one, by Shephard of London, stood at 27.50; afterwards, when we were engaged about the wreck of the masts, it was reported to me as standing at 27 inches; in fact, altogether out of sight. The wind commenced at east-northeast; stood in that quarter 24 hours (moderate in early part), veered to northeast, whence it continued steady till we cut away the masts; then it suddenly subsided into a calm, which continued for half an hour; then, without a moment's warning, it opened out in the northwest in a most frightful tornado, so violent that words cannot express its force, and so continued for an hour, when it veered to west, and gradually afterwards to southwest and south, with continued violence. Rain throughout very heavy. Had not the vessel been brought to on the port tack, as Horsburgh directs, when the wind shifted after the lull, the vessel must certainly have gone down stern foremost; as it was, the gust taking her over the stern, she came up to the wind, and so lay in safety during the remainder of the cyclone.

[*Note.* — The interests of navigation require it to be stated, that on the evening before the disaster Captain Crowe had, in the falling state of the barometer, and the direction of the wind, sufficient evidence to show that *near by, in the southeast, was a typhoon, then crossing his path.* Had he wore ship at this time, or even brought to on the starboard tack, till the wind should have veered eastward and the barometer commenced rising, he would have sustained no damage. But in maintaining his course under the unchanging northeasterly wind, and falling barometer, he pushed directly into the heart of the cyclone; as has too often been done by others.

Commander Rodgers was fortunate in falling behind the violent portion of this terrific cyclone, and was thus able to escape its force without changing his track. He appends the log-book records of the John Hancock, from which it appears that at 3 P. M. of May 20th the barometer had fallen to 29.60; the wind having veered by the northwest to west by north; its greatest force 6; the course of the vessel about north-northeast. Latitude at noon, 11° 55′ N., longitude 111° 17′ E. This corresponds to the Harkura's *nautical* date of 21st; her distance from the John Hancock then being 195 miles; the vortex at that time, somewhat nearer. From 3 to 6 P. M. the barometer rose but little. Later in that day the wind was west by south, and then variable, the barometer rising to 29.80. The 21st commenced with wind at south-southeast, which continued so till noon, in latitude 13° 51′ N., longitude 112° 47′ E. Course north by east. After noon, the wind varied from south-southeast to east, diminishing in force to 3. — W. C. R.]

sky at times between the slowly moving cumuli. In the afternoon, about 3 P. M., being on shore, I heard some peals of far-off thunder, seemingly to eastward; the same had been noticed on board ship. A range of mountains obstructed the sight to northeast, east, and southeast; in the latter direction I perceived the high, white tops of heavy clouds (cum. str.) some distance off. Occasional rain-squalls passed on both sides of us. In the evening the squalls were more frequent, it rained often and profusely; the sky became overcast and hung round with dark-looking clouds, especially to southwest, where we could see the horizon. At 8 P. M., barometer 29.859; sympiesometer 29.896; aneroid 29.822; temperature of air 81°.1; of water 78°.7; of rain-water 75°.2.* About 8 P. M., flashes of vivid lightning to east and northeast, and peals of heavy thunder, occurred, which were repeated several times until 10 P. M., at intervals, stronger or fainter.

October 28th, 4 A. M.—During the night the squalls came from northeast, and increased much in violence. About 4 A. M. the wind hauled to eastward and began to blow more steadily. The rain fell all night and morning very abundantly and in large drops. Barometer 29.654; sympiesometer 29.675; aneroid 29.630; temperature of air 80°.6; water 77°.6; rain-water 75°.7. Towards 6 A. M. the wind hauled to southeast by east, increasing; it lessened somewhat about 8 A. M., but regained soon its former strength from east by south. Rain now fell incessantly, but in smaller quantity. Temperature of rain-water 77°. The weather had a very dark and threatening appearance; a thick mist covered the horizon seawards; the surf broke high and violently on the reef near the entrance of the harbor, and on the rocks outside.

At 9 A. M., barometer 29.471; sympiesometer 29.465; aneroid 29.450; temperature of air 81°.1; water 77°.7; rain-water 77°; wind

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* Mr. Schönborn appends an excellent diagram, showing the fall and rise of the barometer under the successive winds of this cyclone as it passed over the ship, as determined by frequent and careful observations. He adds also the curves indicating the movements of the sympiesometer and aneroid during the same period. It is a graphic exhibition of the cyclonic action, and affords a test of the relative value of the several instruments, under the successive phases of the storm. He adds two other diagrams of like character; one of which, together with that just noticed, I have reduced for these pages, so far as relates to the barometer. I regret that they could not be reproduced entire on this occasion. — W. C. R.

BARO.
28.30
.60
.70
.80
.90
29.00
.10
.20
AT PORT TRAVIS, BIRNIN ISLANDS.
LAT. 27° 05' 15" N.
LON. 111° 21' 30" W.

southeast by east, force 7. After 10 A. M. the wind increased continually, shifting by degrees to southeast; the barometers and sympiesometers fell rapidly. A water-spout was observed at 11 A. M. in the mouth of the harbor moving quickly southwestward. It had nearly the height of the neighboring south bluff, behind which it disappeared. By going over the breakers, a great quantity of spray was carried away with it, whirling around the cylinder. The clouds were not defined except the scud, which flew swiftly at no great distance above us. Shortly before noon the weather became thicker; the surrounding hills appeared as indistinct shadows; indeed, we were sometimes so entirely enveloped in mist and fog, that we could not see a ship's length around us.

Noon, barometer 29.123; sympiesometer 28.956; aneroid 29.100; temperature of air 79°.8; water 77°.7; rain-water 75°.7; wind southeast one half east, 10. At 1.45 P. M. the wind had attained its greatest force, and blew with unabated fury until 3.30 P. M., veering in this time from southeast by south gradually to southwest one half west. There was no calm at the climax of the storm noticeable. The sympiesometer stood lowest at 2.20 P. M. (at 28.233, wind south by west), and the barometer and aneroid at 2.30 P. M. (at 28.443 and 28.482, wind south one half west).* All three instruments remained but a few minutes at their lowest position, and rose then as rapidly as they had fallen. It rained almost continually, rather lightly, but the drops fell with great violence, and made me at first believe them to be mixed with hailstones, which idea however I found contradicted by examination and by the temperature of the rain-water. As the wind turned to the westward of south, there came a heavy swell through the entrance of the harbor, which increased as the wind hauled more to the west. After 3.30 P. M. the force of the wind diminished slightly.

At 5 P. M., barometer 29.169; sympiesometer 29.060; aneroid

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* The nearest approach of the axis or centre was indicated by these lowest observations. As the gradual veering of the wind was in accordance with the apparent course of the sun, and no lull or remission having occurred at the crisis of the gale, it is evident that the observers were to the right of the axis-path, which swept round to the southward and westward of Port Lloyd. At this time it had partially completed its recurvation, and the cyclone was entering upon its northeasterly progression. — W. C. R.

29.178; temperature of air 77°.7; water 77°.7; wind west by south one fourth south, 10. Towards sunset the weather moderated, the clouds assumed shapes again, and for a short time had a remarkably lurid appearance, the whole atmosphere, filled with vapor, seemed to be lighted up, and gave to the surrounding landscape a yellowish tinge.

At 8 P. M., barometer 29.533; sympiesometer 29.459; aneroid 29.529; temperature of air 77°.6; water 77°.7; wind southwest by west, 8. Fresh squalls of light rain from southwest by south, and west-southwest, passed frequently. The form of the clouds looked loose and jagged. Now and then the sky was partially clear overhead, and the stars were visible even through the thinner mist-like clouds.

October 29th, 4 *A. M.*—Barometer 29.748; sympiesometer 29.652; aneroid 29.744; temperature of air 78°; water 78°; wind west-southwest, 5. The weather has been improving much during the night. At 9 A. M., barometer 29.853; sympiesometer 29.830; aneroid 29.850; temperature of air 80°.8; wind light from the westward; weather very fine.

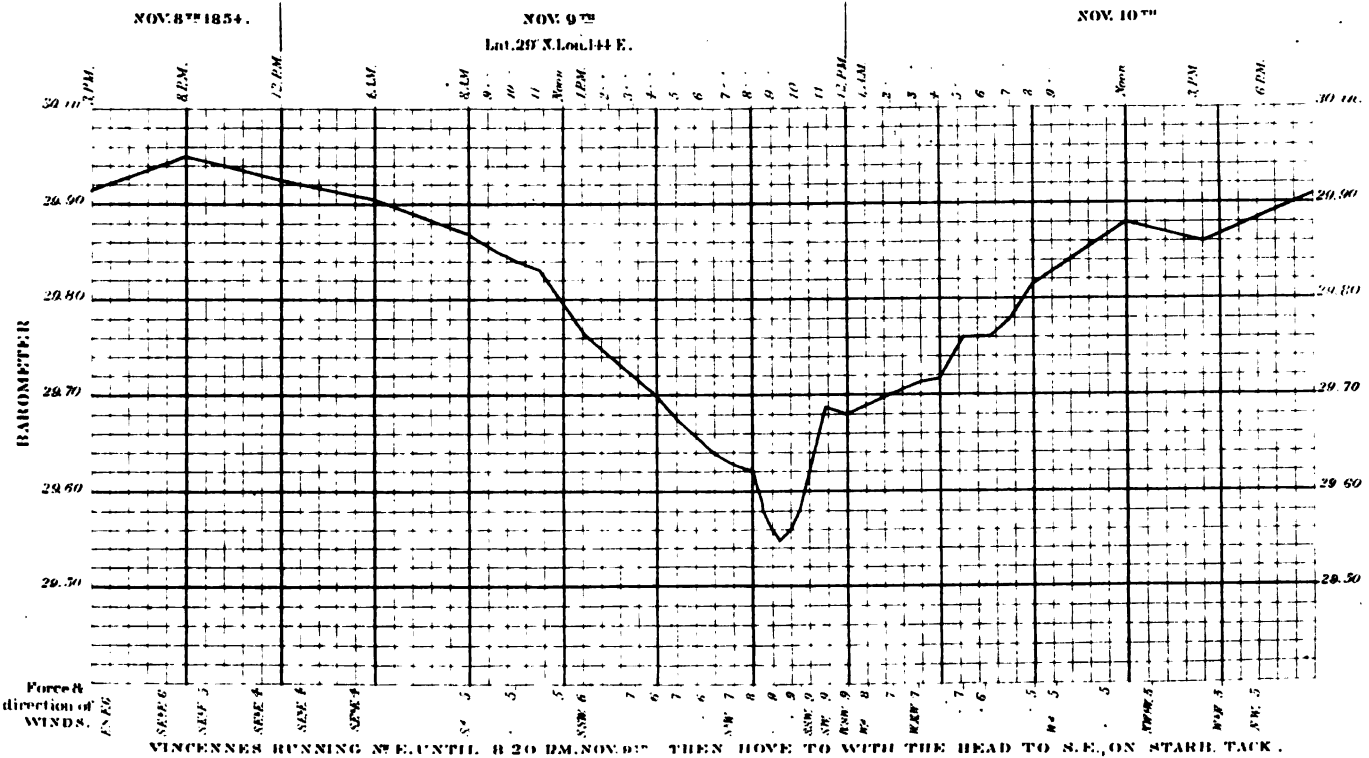
Very respectfully,

ANTON SCHÖNBORN,
Assistant Astronomer.

U. S. Ship Vincennes, November 9th, 1854.

DURING the day we had pleasant weather. A steady south wind blew all the morning, advancing us speedily on our way to the north. In the afternoon the wind freshened, hauling to south-southwest. The barometer and sympiesometer had been falling since 8 P. M. of the previous day, and stood at 3 P. M. at 29.717 and 29.710; temperature of air 18°.1; water 78°.4; wind south-southwest, 7. We were then in latitude 28° 43′ N., longitude 143° 59′ E.

Towards evening, when the sun neared the horizon, he glanced with unusual brightness through the clouds, and the sunset was magnificent. The gilded edges of the cumuli to northwest contrasted finely with the dark appearance of the cloud-bank which began to rise on the horizon. South and westward the upper and lower strata of clouds exhibited a great variety of colors, from pale yellow to brilliant purple, and some of them, which passed swiftly overhead,



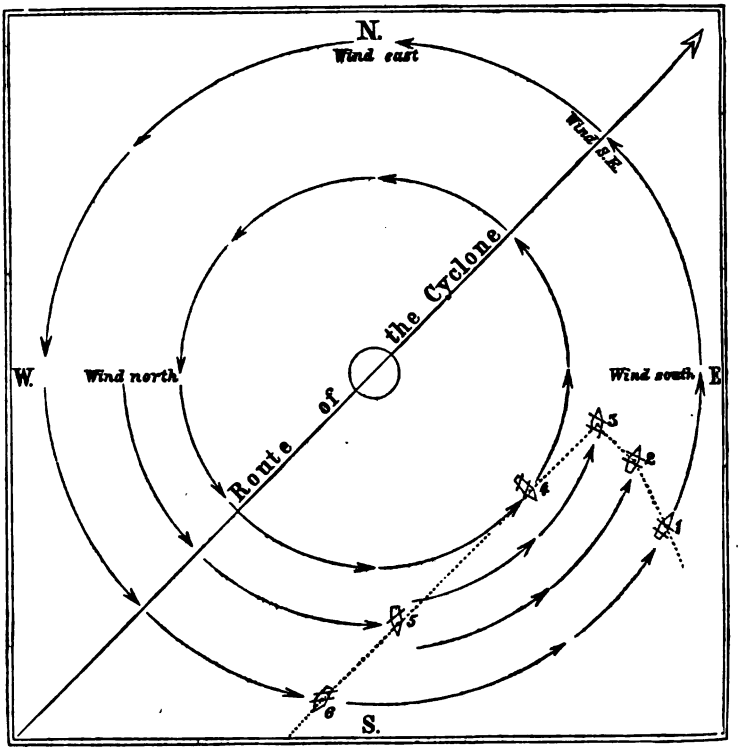
VINCENNES RUNNING N°E. UNTIL 8 20 P.M. NOV. 9TH THEN HOVE TO WITH THE HEAD TO S.E., ON STARB. TACK.

Observed & drawn by Anton Schonborn (Retraced by WCR.)

were even of a greenish hue. A low, compressed mist, orange-colored, lay on the water to the west, serving as a line of demarcation between the calm and beautiful sky above and the already troubled sea below.

As the glow of the sunset lessened, the cloud-bank to the northwest began to rise, and when it became dark, flashes of vivid lightning followed each other in rapid succession, illuminating at times the whole northwestern part of the heavens. The wind veered back to south by west, increasing considerably in force, accompanied by sudden puffs. The waves became high and irregular, owing to a cross swell from south and northwest. A thick mist enveloped us sometimes so that only a small space overhead was clear. The barometer fell constantly. At 8 P. M. *the ship was hauled by the wind on the starboard tack, with the head to the eastward.* The barometer and sympiesometer stood lowest at 9.20 P. M. (29.548; 29.572). At this time also the wind was most vehement from south-southwest. The barometer began to rise after half past nine o'clock. Towards midnight the weather moderated slightly. The wind blew in gusts from the southwest, veering by degrees to westward, and some showers of rain fell. At 4 A. M., on the 10th, the force of the wind had greatly diminished, hauling to west-northwest, and the weather cleared up.

It is very probable that we were in the southeastern wing of the cyclone. From the collected facts the following diagram has been constructed. By the general appearance of the sky and the swell, which came at first from northwest, and afterwards from north, it seemed that the storm moved to northeast. We ran at first into it, — and by lying to, the storm left us, passing on its way to northeast. We entered the circle at No. 1, with a course of north-northeast, which was soon after changed to north by east; our position on the diagram, therefore, became successively that of No. 2 and No. 3.



Position No. 1, November 9th, 2 P. M. Wind south-southwest; ship's course north-northeast, which was changed at 4 P. M. to north by east.

No. 2, at 6.30 P. M. Wind south-southwest; ship's course north by east; cloud-bank to northwest (toward the centre of the storm).

No. 3, at 8.20 P. M. Wind south by west; ship's course north by east; after which the ship was hove to, head eastward.

No. 4, 9.20 P. M. Wind south-southwest; lowest barometer; strongest wind. (Nearest the centre.)

No. 5, November 10th, 1 A. M. Wind westward. Weather moderating.

No. 6, 3 A. M. Wind west-northwest.

4. Results of a Series of Meteorological Observations made at New York Academies from 1826 to 1850. By Franklin B. Hough, of Albany.

Abstract.

The recommendation of this Association in 1851* was successful in procuring from the New York Legislature an appropriation for publishing the results of a series of meteorological observations made at sundry Academies under the direction of the Regents of the University, at sixty-two academies, during a quarter of a century, and an aggregate period of 773 years. A reference of my paper of 1851† will give a synopsis of the kind and extent of the subjects of observation, and I will, on this occasion, limit myself to a concise statement of the leading results of the series under consideration.

From want of uniformity in the returns, the records of periodical phenomena could not be satisfactorily arranged for comparison; but it may be stated as a general rule, that the blossoming of plants and other harbingers of spring occur from two to three weeks earlier on Long Island than in the northern and western parts of the State, while in the latter the first frosts and snows indicating the approach of winter are seen nearly a month sooner. From rapid growth in the colder sections, the harvest of spring grain occurs at nearly the same time throughout the State.

The first appearance of birds of passage is much more uniform, the extreme intervals of the same species seldom exceeding a week.

The mean temperature for the whole time, at all the stations,‡ was 46°.74, distributed through the several months as follows: —

Months.	First Half.	Second Half.	Whole Month.	Months.	First Half.	Second Half.	Whole Month.
	°	°	°		°	°	°
January,	25.17	24.19	24.68	July,	69.12	70.23	69.67
February,	21.68	26.59	24.11	August,	69.94	66.99	68.46
March,	31.02	35.86	33.44	September,	62.14	57.60	59.87
April,	43.05	47.58	45.30	October,	50.49	46.05	48.27
May,	53.37	59.06	56.21	November,	41.24	34.11	37.67
June,	63.72	67.49	65.60	December,	29.19	25.30	27.24

* See Proceedings of this Association, 1851, p. 397.

† Ibid., p. 168.

‡ Parts of years were uniformly omitted in the tabular summaries, as tending to produce unequal results.

The following table shows the names and location of stations at which observations were made, with their elevation above tide, number of years reported, and the extreme and mean temperature of each.

Academies and their Location.	Elevation above Tide.	No. of Years Observed.	Thermometer.					
			Mean Temperature.	Highest Degree.	Lowest Degree.	Extreme Range	Mean Range. Monthly.	Mean Range. Annual.
	Feet.		°	°	°	°	°	°
Albany, Albany Co.,	130	24	48.60	97	—23	120	67.5	100
Amenia Seminary, Dutchess Co.,	540	1	46.73	96	—16	112	45.5	112
Auburn, Cayuga Co.,	650	22	46.62	96	—14	110	68	96
Bridgewater, Oneida Co.,	1,286	4	42.66	94	—31	125	70.5	112
Buffalo, Erie Co.,	623	2	46.14	92	—22	114	55.5	114
Cambridge, Washington Co.,	?	14	45.39	98	—36	134	74.2	116
Canajoharie, Montgomery Co.,	284	3	45.77	97	—36	133	62	118
Canandaigua, Ontario Co.,	707	10	45.73	94	—11	105	62	96
Cayuga (Aurora), Cayuga Co.,	447	13	49.16	96	—10	106	63.2	94
Cherry Valley, Otsego Co.,	1,335	15	44.27	98	—30	128	73	105
Clinton (East Hampton), Suffolk Co.,	16	17	48.74	95	— 8	103	61.5	88
Cortland (Homer), Cortland Co.,	1,096	18	44.67	95	—28	123	71.5	105
Delaware (Delhi), Delaware Co.,	1,384	2	46.66	93	—17	110	59	110
Dutchess (Poughkeepsie), Dutchess Co.,	?	16	50.61	102	—22	124	73	106
Erasmus Hall (Flatbush), King's Co.,	40	24	51.62	96	— 4	100	59.5	87
Fairfield, Herkimer Co.,	1,185	19	43.26	96	—26	122	72.3	105
Farmers' Hall (Goshen), Orange Co.,	425	11	47.56	98	—30	128	69.8	102
Franklin (Malone), Franklin Co.,	703	3	43.54	94	—24	118	65	109
Franklin (Prattsburg), Steuben Co.,	1,494	10	49.43	100	—19	119	71	106
Fredonia, Chautauque Co.,	728	18	48.38	97	—12	109	65.8	93
Gaines, Orleans Co.,	426	4	46.71	94	— 7	101	57.5	94
Gouverneur, St. Lawrence Co.,	400	12	43.95	100	—40	140	79.8	123
Granville, Washington Co.,	?	14	45.39	102	—31	133	74.5	117
Greenville, Greene Co.,	?	1	48.05	91	—17	108	51.5	108
Hamilton, Madison Co.,	1,127	17	44.82	96	—34	130	77.5	112
Hartwick, Otsego Co.,	1,100	16	46.54	96	—30	126	71	104
Hudson, Columbia Co.,	150	17	47.84	99	—24	123	67.8	102
Ithaca, Tompkins Co.,	417	17	48.38	98	—18	116	70.5	101
Johnstown, Fulton Co.,	688	14	44.91	96	—30	126	72.3	112
Kinderhook, Columbia Co.,	126	17	47.00	102	—30	134	74.5	109
Kingston, Ulster Co.,	188	19	49.57	100	—30	130	71	104
Lansingburg, Rensselaer Co.,	30	20	47.92	101	—28	129	74	114
Lewiston, Niagara Co.,	280	17	47.88	97	— 6	103	65.3	92
Lowville, Lewis Co.,	800	19	43.62	100	—40	140	79	120
Mexico, Oswego Co.,	331	11	49.08	99	—24	123	72	106
Middlebury, Wyoming Co.,	800	19	46.78	100	—20	120	78	103
Millville, Orleans Co.,	?	8	46.11	95	—12	107	65	99
Monroe (Henrietta), Monroe Co.,	600	3	45.84	96	— 9	105	60	97
Montgomery, Orange Co.,	?	13	48.60	104	—33	137	77.5	109
Mount Pleasant, Westchester Co.,	125	12	47.41	97	— 8	105	58.5	93
Newburg, Orange Co.,	150	18	97.67	105	—15	120	69	100
New York Institute Deaf and Dumb,	50	6	51.01	92	— 2	94	49	84
North Salem, Westchester Co.,	361	19	48.06	102	—31	133	74	105
Ogdensburg, St. Lawrence Co.,	280	1	43.48	92	—10	102	44	102
Oneida Conference Seminary (Cazenovia), Madison Co.,	260	19	43.65	97	—28	125	74	109
Oneida Institute (Whitesborough), Oneida Co.,	405	7	44 83	98	—33	131	71.8	115
Onondaga (Onondaga Hollow), Onondaga Co.,	600	16	47.18	99	—22	121	72.8	106

Academies and their Location.	Elevation above Tide.	No. of Years Observed.	Thermometer. Mean Temperature.	Highest Degree.	Lowest Degree.	Extreme Range.	Mean Range. Monthly.	Mean Range. Annual.
	Feet.		°	°	°	°	°	°
Oxford, Chenango Co.,	961	16	44.74	98	—36	134	76.3	114
Oyster Bay, Queen's Co.,	?	2	50.81	95	— 3	92	48.2	90
Palmyra, Wayne Co.,	?	1	45.33	93	— 9	102	54	102
Plattsburg, Clinton Co.,	120	5	45.17	100	—20	120	63	108
Pompey, Onondaga Co.,	1,300	17	42.83	91	—18	109	66	99
Redhook, Dutchess Co.,	?	12	48.36	98	—28	126	68	102
Rochester, Monroe Co.,	506	19	46.79	102	— 9	111	67	95
St. Lawrence (Potsdam), St. Lawrence Co.,	394	31	43.61	96	—34	130	78.3	114
Schenectady, Schenectady Co.,	?	3	45.82	91	—16	107	55.3	101
Springville, Erie Co.,	1,082	7	45.32	95	—20	115	69.2	102
Syracuse, Onondaga Co.,	400	1	47.30	94	— 3	97	45	97
Union Hall (Jamaica), Queen's Co.,	?	25	49.87	100	— 7	107	64.2	92
Union Literary Society (Bellville), Jefferson Co.,	400	9	45.51	98	—35	133	74.5	112
Utica, Oneida Co.,	471	22	45.38	97	—27	124	75	104
Washington (Salem), Washington Co.,	?	10	46.53	100	—40	140	73.8	119
Mean,			46.74				67	103

A comparison of the temperature of the several months, at different stations, shows a greater uniformity throughout the State in summer than in winter, and consequently a more rapid transition of temperature in spring and autumn.

The station having the highest annual mean was at Erasmus Hall (Flatbush), and that having the greatest range was at Gouverneur. The extreme range becomes *less* as the mean becomes *higher*. The annual extremes of seventeen stations which were less than 100° had, with one exception, a mean above that of the State. The mean temperatures of the last half of April and October are nearly equal to that of the year.

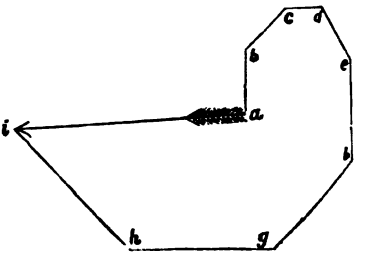
The well-known influence of elevation upon temperature is strikingly shown by comparing the observations of stations near each other, but of different altitudes. A reference to the foregoing table will show a difference between Onondaga and Pompey; Utica and Bridgewater or Fairfield; Poughkeepsie and Amenia; Newburg and Goshen, &c., which can be attributed to no other cause. An isothermal chart, constructed from the observed surface temperatures of places of different altitudes would therefore exhibit nodes and irregularities in its lines, due to inequalities of surface, which could not be understood without an accompanying section of the country, or some notation for indicating the relative altitude of different places.

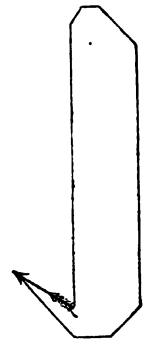
Other influences likewise tend to produce permanent deviations of temperature from that due to geographical position, such as prevailing winds from local peculiarities of surface, the vicinity of bodies of water, character of soil with reference to absorption and radiation of heat, &c. The experience of the series under consideration shows that too much care cannot be taken in observing and reporting the various local causes which tend to modify the results of meteorological records.

The mean direction of the winds for the whole State was S. 80° W. during thirty per cent of the time, the remainder being neutralized by opposite winds. At thirty-four stations the mean was south, and at twenty-eight, north, of the mean of the whole State. One of the most obvious peculiarities in the observation upon winds is the influence of local valleys in the vicinity of the stations. As with minor exceptions the prevailing course of the hills and valleys of New York is north and south, it is highly probable that the true prevailing course of aerial currents across the State is nearer west. A record of the direction of clouds would possess much more scientific value, and should always form a part of a well-conducted series of observations.

In the volume under consideration, diagrams were used to illustrate the effect of local causes upon winds, which at the same time indicated the comparative amount of the several winds.

If, in the annexed figure, the lines *ab*, *bc*, *cd*, *de*, *ef*, *fg*, *gh*, *hi*, represent in direction and length all the winds that blow from the several points in a given month, the arrow *ai*, will represent the resultant of the winds, and the sum of the broken lines *ab*, *bc*, &c., to *i*, the entire period of the month. It is evident that the prevalence of northerly and southerly winds, as at Kinderhook, would give the figure a vertical elongation and very much shorten

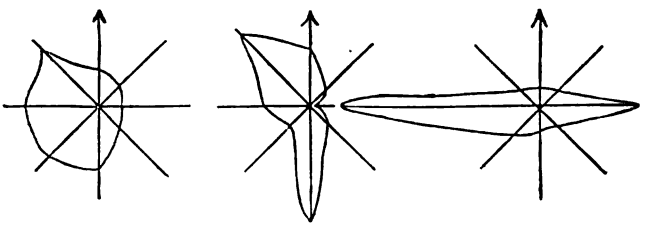




Wind at Kinderhook.

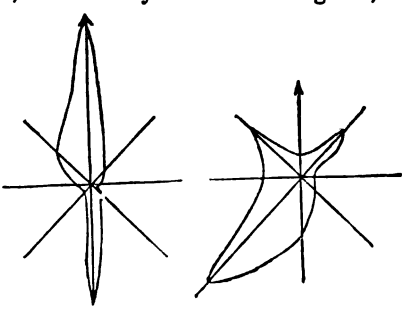
Winds at Utica.

the resultant, while at places situated like Utica, in an east and west valley, the elongation would be horizontal, and the resultant increased in quantity. The relative prevalence of winds may also be shown, and the modifying influences of local causes demonstrated, by laying off from a central point, in different directions, distances proportioned



Whole State. Albany. Utica.

to the prevalence of winds from the several points, and connecting the spaces thus laid off by a line, as shown by the annexed figures, in which the final results of the winds of the whole State, and of Albany, Utica, Kinderhook, and St. Lawrence are delineated. In general, the winds in the State, are more northerly in the first half of the year, and more southerly in the other half, than the annual average.



Kinderhook. St. Lawrence.

The aspect of sky as observed during a quarter of a century, indicates a prevalence of clear open clouds in the proportion of $15\frac{1}{2}$ to $14\frac{3}{4}$, and a progressive increase of serene sky from December to July, from which it declines to December. No scale of cloudiness was used in these observations, the general aspect of sky in the forenoon and afternoon being entered daily.

The rain-gauge records show that more rain falls in the maritime region of the State, and in the valleys of the Hudson, Mohawk, and Susquehanna than in other sections. At twenty-nine stations the mean was greater than that of the whole State (34.9), and at thirty stations it was less. The greatest depth reported was at New York

(46.26), and the least at Lewiston (2 .23). At Buffalo, Gouverneur, Monroe, Ogdensburg, and Potsdam, the mean was below 28 inches, and at Albany, Bridgewater, Cambridge, Cherry Valley, Delaware, Jamaica, New York, North Salem, Oyster Bay, Schenectady, and Utica, it was over 40 inches. The most rain fell in summer and autumn; the least in February and the greatest in June. From May to November the mean was above that of the year. The amount of rain falling in different years varies considerably, and, reduced to monthly means, was as follows: —

Years.	Mean.	Above or below General Mean.	Years.	Mean.	Above or below General Mean.	Years.	Mean.	Above or below General Mean.
1826	2.72	—0.19	1835	2.79	—0.12	1843	3.03	+0.12
1827	3.49	+0.58	1836	2.78	—0.13	1844	2.69	—0.22
1828	3.19	+0.28	1837	2.99	+0.08	1845	2.69	—0 22
1829	2.76	—0.15	1838	2.65	—0.26	1846	2.83	—0.08
1830	3.20	+0.29	1839	2.64	—0.27	1847	3.18	+0 27
1831	3.15	+0.24	1840	2.96	+0.05	1848	3.28	+0.37
1832	3.07	+0.16	1841	2.66	—0.25	1849	2.74	—0.17
1833	3.03	+0.12	1842	3.16	+0.25	1850	3.63	+0.72
1834	2.54	—0.37						

The number of solar haloes observed was 455; of lunar haloes, 439; distributed through the several seasons as follows: —

	Solar.	Lunar.		Solar.	Lunar.
Spring,	196	128	Autumn,	62	93
Summer,	87	51	Winter,	110	167

Generally complex haloes were reported, and figures of the more important of these are given.

Auroras were observed on 1,152 days throughout the entire period, as follows: —

1826	2	1831	55	1835	30	1839	57	1843	56	1847	46
1827	14	1832	24	1836	61	1840	73	1844	30	1848	73
1828	21	1833	37	1837	50	1841	73	1845	24	1849	73
1829	24	1834	35	1838	42	1842	35	1846	47	1850	90
1830	80										

The greatest number of auroras was noticed in September, their distribution through the several months being as follows: —

January	76	April	125	July	100	October	110
February	86	May	83	August	122	November	74
March	106	June	79	September	131	December	60

A list of stations at which auroras were observed beyond the limits of the State, was introduced to show the geographical extent of some of the more remarkable ones. Auroras were noticed on the same days in this State and in Europe on 160 occasions. In none of those seen in this State were comparative observations made with the view of determining the altitude of the aurora.

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5. On the Peculiar Appearance of the Atmosphere on the 23d of May, 1856, at St. Martin's, Isle Jesus, Canada East. Latitude 45° 32′ north, Longitude 73° 36′ west from Greenwich, 118 feet above the level of the Sea. By Charles Smallwood, M. D., of Toronto.

At noon, on Friday, the 23d of May, the southwestern horizon was covered with a rather dense haze, but of a very low altitude. The zenith and eastern horizon were cloudless, and it was not till the two o'clock observation (one of the usual hours for observation at this Observatory) that any particular attention was directed to it. The two o'clock observation is thus recorded.

Barometer, 29.604 inches. *Thermometer*, 78°.9. Dew-point, 62°.0. Elastic force of aqueous vapor, .559. Humidity, .55. Wind southwest. Mean velocity 8.21 miles per hour. Sky cloudless, a peculiar haze in southwest and west-southwest, commencing at the horizon and rising to an altitude of 12°. *Electrometers* indicate very feeble intensity.

3 P. M., *Thermometer* indicated a temperature of 83°.4. *Barometer* falling. Wind southwest by west, 16 miles per hour. At this time the haze which had been observed at noon had increased in density, and had now attained a greater altitude, and in some measure obscured the sun's rays, giving to the sun itself a ruddy color. At 4 P. M. the obscuration was more dense, the heat was very oppressive, and at 6 P. M. the obscuration had so much increased as to completely hide the sun from view. There was no distinct form of clouds present, but there appeared a uniform dense haze.

At 6.15 the following were the observations recorded. The horizon in north-northeast, and extending to east-southeast, perfectly cloudless;

from an altitude of nearly 3° there was a peculiar yellow appearance in that part of the heavens to the visible horizon. From this altitude of about 3° hung, as it were a curtain, this dense mass of hazy matter, of a dull reddish or coppery hue, stretching out at rather a low elevation, completely obscuring the zenith, the southwestern and northwestern horizon. The sun was still completely obscured and invisible; the *barometer* now stood at 29.578 inches; the *thermometer* indicated a temperature of 73°.1. The wind, which at 3 P. M. was blowing 16 miles an hour from the southwest by west, had gradually decreased in velocity, and was now lulled into a gentle calm.

At 6.20 P. M., which is recorded here as being about the time of the greatest obscurity, the fowls had retired to roost, the frogs had begun their croak, the cows had of their own accord left their pasture; the green fields exhibited a peculiar dark-green or bluish hue, which contrasted very strongly with the eastern horizon, which was still clear, presenting a bright light of a yellow tinge. From about 6 P. M. until dark, I was occupied, with my son, in catching leaves and ashes which were carried by the wind. The leaves were of exogenous plants of the class Cupuliferæ and Acerineæ (mostly beech and maple). They appeared scorched and blistered, as if caused by great heat. The ashes continued falling most part of the night, at least till about 2.20 A. M. of the 24th, when the wind veered by the north to due east. On submitting these ashes to examination, I found they consisted of silicious (flinty) matter, leaving a permanent mark on glass. They were also mixed up with light vegetable matter. From the size of the leaves, I presumed they were not of this year's foliation, and this was verified upon further examination; and this may account in some measure for the distance they were carried, and no doubt aided by the dense medium by which they were surrounded, or in which they floated. They were all caught before reaching the ground, so that no error could possibly occur.

I shall now give a report of the appearances as they occurred at Bytown. The newspaper says: —

"On Friday afternoon last, the wind brought up, apparently from the rear of the Gatineau Mountains, opposite this city, a vast cloud, which gradually rose to the zenith, and finally spread over the whole face of the heavens. A more extraordinary appearance we never saw. The cloud itself, particularly towards the zenith, was of a lurid

copper color, while towards the quarter from which the wind came there was a large spot of lighter color, absolutely fiery, very like what sailors call the 'ox-eye,' which is seen amidst the masses of dark clouds which prelude a hurricane on the west coasts of Africa. It is no exaggeration to say, that the scene was a most awful one, and every one expected a tremendous outbreak of the powers of nature; some predicted an awful thunder-storm; others a hurricane of wind and deluge of rain; but nothing came of it; the clouds gradually passed away, and the evening was fine. During the continuance of this dense cloud, a few ashes and some burnt leaves fell in the streets in various places, and our own opinion is, that all this most remarkable appearance was the result of an enormous fire in the forest, far up on the southern slope of the range of mountains which terminate on the Saguenay, passing behind Three Rivers and Quebec. If it be so, the conflagration must have been of an astounding character to have produced such results here, and it is evident that the scene of the fire must have been far off, and probably in a tract of land where none but the red man puts his foot, for we have heard of no fire anywhere near civilized settlements in that direction.

"On the next morning, Saturday, we experienced a heavy thunder-storm, with rain, and in the afternoon there was a little thunder, with showers. The heavy rain of Saturday must have swelled the tributary streams, and so will aid the timber-driving."

"Since the publication of our paper, this morning, we have received a communication from Pembroke, the substance of which we communicate to our readers in the form of an extra. The extraordinary phenomenon of Friday, alluded to in our columns of to-day, is now fully accounted for; but we must confess ourselves at a loss to understand how a vast cloud of smoke arising from a fire above Pembroke, could make its first appearance here from behind the mountains which skirt the township of Hull. We can only account for it by applying Reid's theory of storm, that the wind blows in circles, and that the storm of wind which brought the great cloud past this city must have circled to the westward from Pembroke. We may be talking nonsense, for we pretend to no accurate acquaintance with meteorology, but in our simplicity can account for the phenomenon in no other way. Our correspondent says that a great fire broke out in the woods near Pembroke on Friday, that many farmers were burnt out, and that nothing was expected but the destruction of the whole town. The wind fortu-

nately changed, but all the inhabitants had everything ready to take to the river as their only chance of safety.

"On the Petewawee River, ten miles from Pembroke, the women and children had to take to the river to save their lives; two or three saw-mills, a tavern, and all the houses in the settlement, are destroyed. In Pembroke, at two o'clock on Friday, nothing could be seen but sheets of flame, which appeared to surround the place; the sun was as red as blood, and the whole sky seemed in a blaze; the scene was so frightful that many people believed, in their terror, that the Last Day was at hand. No one thought of saving any of their possessions; the only thought was to escape by getting into the river. About eight o'clock at night the wind, which had been blowing straight for Pembroke, calmed down, and the town was saved. At four in the afternoon the smoke was so dense that the people were almost on the point of suffocation, and it was so dark that no one could see across the street. All describe the scene as a most frightful one. We have heard of thirty families burnt out, and who narrowly escaped with their lives. Our correspondent says, that the sound of the roaring flames actually shook the ground, and the noise of the falling trees was like the rattling of a line of heavy wagons over a corduroy road; the country about is half ruined, and a number of bridges have been burned. We are promised further particulars."

Such were the appearances within 60 miles of the conflagration, and the distance from Pembroke to St. Martin's is not less than 200 miles. Burnt leaves and ashes were picked up in Montreal, and the amount of ashes in this neighborhood was very considerable.

The peculiar appearance of the atmosphere at this place was caused no doubt by the interception of the solar rays by dense haze, consisting of smoke and vapor. The white light was absorbed, giving rise to the predominant yellow ray. The green fields were of a bluish tint. It would seem that it was only the light ray that was intercepted. The *calorific ray* does not seem to have at all absorbed, for there was no fall of the thermometer; in fact, the heat was oppressive. The *chemical* or *actinic* ray seems also to have retained its action, for chromatype paper exposed was easily acted upon, as was also paper wetted with the solution of nitrate of silver. I had no opportunity of examination with the polariscope; the prismatic spectrum was deficient in the yellow ray. I may remark, that a very violent storm of thunder and lightning occurred on the following morning.

PART II.

NATURAL HISTORY.

I. GEOLOGY AND GEOGRAPHY.

1. PLAN OF DEVELOPMENT IN THE GEOLOGICAL HISTORY OF NORTH AMERICA. — With a Map. By PROFESSOR JAMES D. DANA, of New Haven.

ON other occasions, I have discussed at some length, the outline and surface features of the continents, the parallel courses of island groups, and the relations between the structure of the continental borders and the extent of the adjoining oceans; and I have endeavored in connection to elucidate the great principle of geological dynamics, which is at the basis of these characteristics of our globe.* I propose at this time to point out the relations between the operations of this principle or agency and the special geological history of the North American continent.

To render this application of the subject intelligible, it is necessary to review briefly the fundamental facts just alluded to. For this purpose, I would direct attention to a Mercator's Chart of the World (see plate), on which the whole is open to examination, — such a chart being a miniature representation of the facts themselves, and the order observed among its parts, the syllables which spell out the principles.

* Am. Jour. Sci., [2], ii. 335, 352, iii. 94, 176, 381, iv. 88; Report, Geol. Expl. Exped., 756 pp. 4to., 1849, pp. 11, 414, 429; Proceedings Amer. Assoc. vol. ix. Providence Meeting, 1855.

In the first place, note the two great oceans, the Atlantic and the Pacific, — both widening south, and coalescing in a vast ring of ocean around the south pole, while narrowing north and uniting in a small arctic sea. The Indian Ocean is a third north and south ocean; but it reaches north only a little ways beyond the equator.

As the Atlantic is less than half the breadth of the Pacific, so the American continent is less than half the breadth of the great Orient, including Europe, Asia, and Africa. It is seen also that while the North Atlantic trends off to the north-east, and the whole Atlantic is a zigzag channel with a main *north-east* course, the Pacific is a *north-west* channel, its longest diameter (represented by the line M M), being at right angles nearly with the trend of the Atlantic (N N). This longest diameter, moreover, corresponds with the general trend of the Pacific islands; for these islands have a nearly parallel course all through the ocean, the New Hebrides, Kingsmills, Samoan, Tahitian, Marquesas, and Sandwich islands, lying in approximately parallel lines.* In the

* I may here add, what I have elsewhere explained at length, that the trends of the Pacific, while having a general correspondence of direction, pertain to two systems, one the Central Pacific, the other the Australasian. The Central Pacific begins in the Paumotu Archipelago, or rather still further east, in Easter Island and Gomez; is thence continued on a west-north-west course, by the Society Islands, and the Hervey Islands more south; thence by the Samoan and Fakaafo groups; thence more north-westerly by the Vaitupu and Kingsmills, to the Radack and Ralick groups, which run nearly north-north-west; making thus a great sweeping curve, of several strands, over 6,000 miles long. The Sandwich or Hawaian islands on the north side of the equator (2,000 miles in whole length) is the opposite or northern side of the same system, slightly curving with the convexity to the north: while the Marquesas and the Fanning or Washington group lie along the axis of this great Central Pacific area. The other system is concentric around Australia, (New Holland). The line of New Hebrides, near north-west in course, is continued in the Salomon Islands, and New Ireland, becoming gradually east and west in the Admiralty Islands, north of New Guinea. The line of New Caledonia, another curving strand in the system, is continued in the Louisiade group and New Guinea, and becomes east and west in western New Guinea. The foot of the New Zealand boot, and the Coral Archipelago between New Caledonia and Australia, accord with the system. The position of these lines concentric around Australia corresponds with the idea that the position and extent of this continent has had some influence in determining the directions.

These two systems, the Central Pacific and Australasian, though so distinct, are yet bound together in one. For while the great central range has its main course

body of New Zealand, however, and some other parts, the transverse trend of Eastern America is represented.

Now what is the relation between the borders of the continents as to features and structure, and the extent of the oceans?

1. Look first to North America. Observe the general direction of the coast conforming to the prevalent trends of the globe, the north-east and north-west, and thus giving it its triangular form. See the low Appalachians facing the *small* Atlantic, the lofty Rocky Mountains, mostly a double line of heights, facing the *broad* Pacific, besides a second towering range, the Cascade and Sierra Nevada, nearer the sea. May we not say, *As the height of the Appalachians to the size of the Atlantic, so is the height or extent of the Rocky range to the size of the Pacific?*

In South America, there is the same relation, — the low Brazilian mountains on the Atlantic side, the lofty Andes on the Pacific, and the latter exceeding the Rocky Mountains as much as the South Pacific exceeds the North Pacific; so that we may make another proportion, *As the height of the Rocky Mountains to the North Pacific, so is the height and boldness of the Andes to the South Pacific.*

In the Orient, the mountains towards the Atlantic, or those of Europe, are low and limited, compared with the long and lofty ranges of the Pacific side; and these last are inferior to the Himalayas, the sublimest heights of the world, which face the Indian Ocean, — a large and open ocean, while the Pacific towards Asia is much encumbered by islands.

In Africa, the loftiest and longest mountains are those of Abyssinia, on the east, facing the Indian Ocean, some of whose ridges are eleven to fourteen thousand feet in height, and one peak near the equator is 20,000 feet. In Australia, the Australian Alps, as they are called, are on the east fronting the Pacific, here the wider of the bordering oceans.

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along the Kingsmills and Radack groups, it sends off at the Kingsmills, a western branch, the Carolines, which is actually parallel with the lines of the Australasian system.

The transverse trend of New Zealand, which is continued in the Friendly Islands north, is the correlate of the north-western, the two having a mutual dependence, and together distinguishable in many groups of islands as well as in the features o the continents.

Thus all over the world, the highest mountains stand fronting the largest and deepest oceans; and the "rule of three" statement of the fact scarcely conveys a wrong impression.

2. We observe further that the coasts are in general so turned as to face the widest range of ocean. The Appalachians with the neighboring coast do not face north-east towards the European continent, but south-east, towards the great opening of the Atlantic between America and Africa. So on the west side of North America the Pacific coast faces, not towards Asia, but south-west, where the broadest range of ocean is before it.

3. Consider now a little more closely the structure of these ocean borders. How is it as to the effects of heat or volcanic action?

In North America, on the side of the *small* ocean, the Atlantic, we find metamorphic rocks, some trap dykes, and a few tepid springs. On the side of the *great* ocean, the Pacific, all these phenomena occur, and besides, some of the grandest volcanoes of the globe, while basaltic floods have buried out of sight almost all other rocks over a considerable part of the country. Mount St. Helens, Mount Hood, Mount Shasta, and many others, twelve to eighteen thousand feet high, make a majestic file of fire mountains not yet wholly extinct. May we not then say, *As the size of the Atlantic to the action of heat on the Atlantic border, so is the size of the Pacific to the action of heat on the Pacific border?*

In South America, there is a direct repetition of the same facts on a still grander scale: the Brazilian side, with metamorphic rocks and no volcanoes; the Pacific side, with volcanic heights of 20,000 feet and upward.

In the Orient, there are some small volcanic operations on the Atlantic side; but an unnumbered host down through Kamtschatka, Japan, and the islands south on the Pacific side.

In Africa, there are great volcanoes in the Red Sea and the lofty Abyssinian mountains, and only a few on the east, in the Gulf of Guinea, where, in fact, the continent opens on the Southern Ocean and not simply on the narrow Atlantic; the volcanoes are at the junction of the two lines, in or near the Bight of Biafra.

4. Again, these effects of heat are confined mostly to the region between the crest of the border mountains and the ocean, and are most intense towards the coast line. Thus the crystallization or metamor-

phism of Eastern North America, from Labrador to Georgia, is strongly marked towards the ocean, and diminishes going westward. So on the Pacific side: the great volcanoes are not on the east or landward side of the crest, for there is not a volcano on that side, but on the seaward side, and not very far from the ocean. Thus we may almost say, *The nearer the water, the hotter the fire.*

5. Again, the mountains that make the borders, consist as is now well known since the surveys of the Professors Rogers, of rocks that have been pressed up out of place into a series of immense folds, like the folds we may make in paper by pressing laterally; only the rocky folds are many miles in range and of mountain height; and these folds or plications and displacements are most numerous towards the ocean, and are parallel nearly to the ocean. Hence again, *The nearer the water, the vaster the plications of the rocks.*

6. Over the interior of North America, there are not only no volcanoes, but there never have been any since the earlier Silurian, as shown by the absence of their remains among the strata; and this is so, notwithstanding the abundance of salt water over the regions in those ancient times. Over the interior of Asia there are no volcanoes, as is well known, except the three or four in the Thian-Chan Mountains. The great volcanic belt of the Orient stands out a short distance from the water-line of Asia, in the Japan range of islands, thus directly edging the oceanic basin; for the intervening region of shallow waters is properly a submerged part of the continent.

7. In contrast with this non-volcanic character of the interior of the continents, the islands of the oceans, it should be remembered, are all volcanic where not coral, and those of coral probably rest on a volcanic basis. Dhawalagiri, in the Himalayas, 28,000 feet high, is granitic; and surely we might have looked for some granitic peaks among the central islands of the oceans: but there are none.

At the same time, as others have remarked, the transverse seas which divide the Northern and Southern continents, the East Indies, the Mediterranean, and West Indies, are characterized by volcanoes.

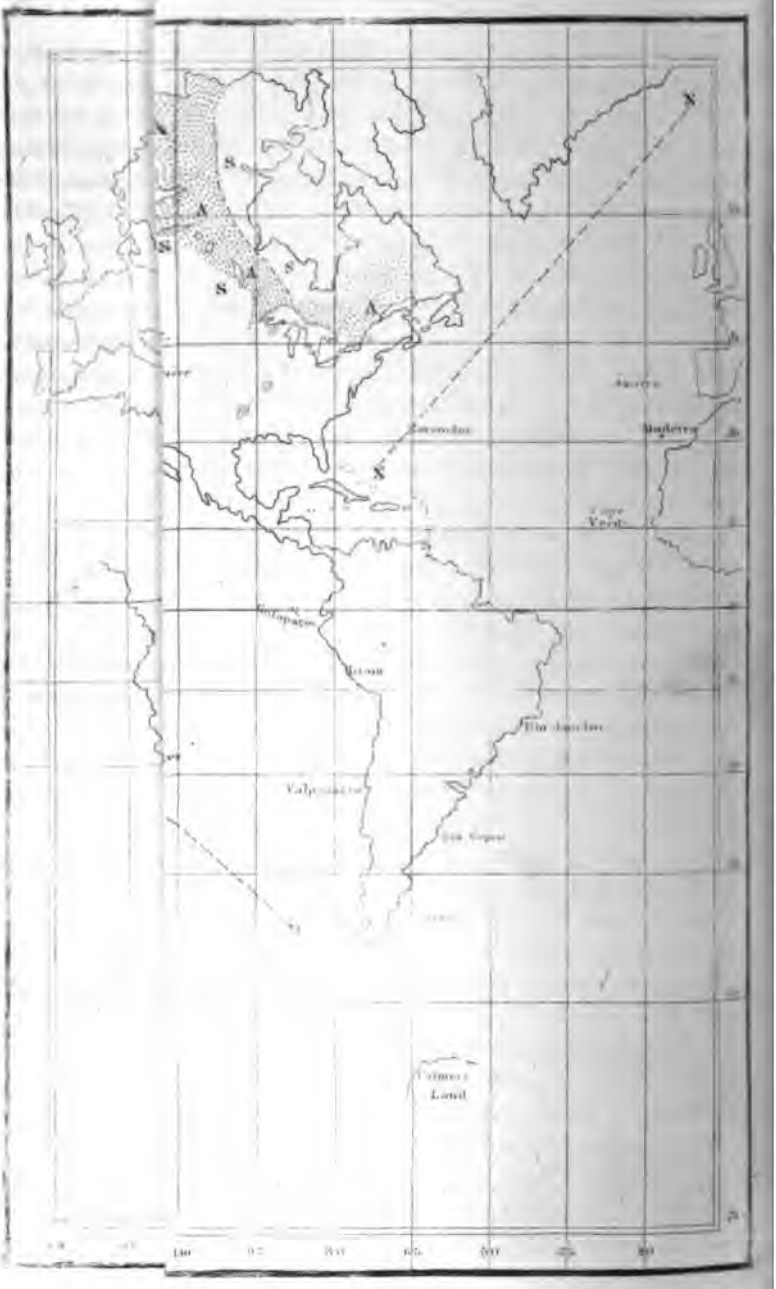
If, then, the typical form of a continent is a trough or basin, the oceanic borders being raised into mountains; if these borders are so turned as to face the widest range of ocean; if the height of these border mountains and the extent of igneous action along them is directly proportioned to the size of the oceans, — the Pacific, accordingly, being

girt with great volcanoes and lofty mountains, while the narrow Atlantic is bounded by smaller heights and but few volcanoes; if, moreover, volcanoes characterize the islands of mid-ocean and not the interior of the continents: What is the legitimate inference?

Most plainly, that the extent and positions of the oceanic depressions have some way determined, in a great degree, the features of the land; that the same cause which originated the one, impressed peculiarities on the other; that the two had a parallel history through past time, — the oceanic depressions tending downward, the continents upward; in other words, that they have both been in progress with mutual reaction from the beginning of the earth's refrigeration. The continents have always been the more elevated land of the crust, and the oceanic basins always basins, or the more depressed land.

We thence learn that the profounder features of the earth were marked out in the earliest beginnings of geological history, and that the whole subsequent progress has been a working on this basis. Other and more direct evidence of this fact I alluded to in my address before this association last year, — evidence derived from the extent and nature of the Potsdam sandstone, the earliest of the Silurian strata, showing that this primal rock was laid down over a large part of North America by a sea which just bathed its surface, — thus proving that the continent was already made, and indicating in part its water level.

The relation between the extent of the oceans and the border features of the continents, which has been pointed out, is not simply a relation of fact, but of effect and dynamics, pointing to a unity of cause. The one cause is assuredly not in the waters of the oceans, for these are inert: they cannot bake rocks, light up volcanoes, fold the heavy strata, and make mountains. The cause is no paroxysmal force, exhausted in a temporary freak of nature. It is some profound, systematic, untiring force, which, in its slow movement, has counted centuries as if seconds. The Appalachian range is one mark of its power; but not the result of a fitful heave: on the contrary, a work of time, and time so long, that the resisting strata could bend in many plications without being reduced to chaos; so long, that New England and regions south, which entered the period of catastrophe as a territory of sedimentary beds, came forth at last a region of granite, gneiss, and crystalline chists. Most of the mountains of the globe, for the reasons stated,


N
S
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Madeira
Cape Verde
Rio de Janeiro
Falkland Islands

After this review of principles, let us now turn our attention to North America and seek out its plan of development.

I. The triangular form of the continent has been noted and its simple ocean boundary: and it should be observed that the continent is set quite to the west of South America, so as to possess this simplicity of boundary and therefore of moulding forces in its highest perfection.* The small Atlantic on one side, and the great Pacific on the other, indicate approximately the relative amounts of force from the two directions, the south-east and south-west, during the progressive ages of the history; — that to the eastward the power was comparatively moderate, gently folding up the Appalachians, and to the westward it was strong and mighty, even to the raising of the Rocky range and opening the great volcanoes of Oregon. We thus learn, with a degree of precision not to have been anticipated, the direction and efficiency of the great organizing forces.

Glance now at American geological history from this point of view, and consider where was the first germinant spot of the growing continent, and what was thence onward the course of development under the influence of this agency.

The earliest spot or primal area will be that of the Azoic rocks, the first in the geological series. Such an area (see Chart, A A A) extends from Northern New York and Canada, north-west to the Arctic Ocean, lying between the line of small lakes (Slave, Winnipeg, etc.) and Hudson Bay. East and west, it dips under Silurian strata (S S); but it is itself free from superincumbent beds, and therefore, even in the Silurian age, it must have been above the ocean. And ever since, although subject, like the rest of the world, to great oscillations, it has apparently held its place with wonderful stability, for it is now, as probably then, not far above the ocean's level.

This area is central to the continent; and, what is of prominent interest, it lies parallel to the Rocky Mountains and the Pacific border, thus proving that the greater force came from that direction in Azoic times, as well as when the Rocky Mountains were raised. Thus this first land, the germ or nucleus of the future continent, bears in itself

* The contrast with Europe in this respect is striking, and accounts, as I have said, (Address, &c., Proc. Amer. Assoc. vol. ix. p. 10, 30,) for the greater simplicity of North American Geology.

evidence with respect to the direction and strength of the forces at work. The force coming from the Atlantic direction has left comparatively small traces of its action at that time. Yet it has made its mark in the Azoic stretching through Canada to Labrador, in the dip and strike of the New York Azoic rocks, in the direction of the channel of the St. Lawrence and the north-west coast of Lake Superior, as well as the bearings of the Azoic of Missouri and Arkansas, and probably also in the triangular form of Hudson's Bay. Against this primal area, as a stand-point, the uplifting agency operated, acting from the two directions, the Atlantic and the Pacific; and the evolution of the continent took place through the consequent vibrations of the crust, and the additions to this area thereby resulting; the ocean in the mean time pursuing its appointed functions in the plan of development, by wearing exposed rocks and strewing the shores and submerged surface with sand, gravel, or clay, or else growing shells, corals, and crinoids, and thus storing up the material of strata and burying the life of successive epochs.

These long secular vibrations, movements by the age rather than day, dipping the surface and raising it again in many and varying successions, were absolutely essential to the progress. Had the continent been stable, there could have been no history, no recorded events of changing life and alternating deposits: all would have been only a blank past. These forces, therefore, working mainly from the south-east and south-west, were actually organizing forces, essential to the completion of the continent, — to the production of its alternations of limestones, shales, sandstones, and conglomerates, and its sweeping catastrophes burying the old, preparatory for higher, forms of life; — the continent in the course of these movements, being at one time, it may be, just beneath the ocean's surface, and having beds of sand and gravel accumulating under the action of the waves; then in somewhat deeper and clearer waters, with limestones forming from coral or crinoidal plantations or the growth of shells; then, perhaps, rising from the waves, bringing death upon its sea tribes in one universal desolation; then, sinking slowly in the waters again, and varying in its accumulations from sandstones to shales, pebble beds or limestones, with the depth and the currents; and then again above the tides, although destruction to all the life of the ocean was in the movement; and, perchance, lying in the open air for an era, to receive the mists and rains

and sunshine, and become luxuriant through new creations with broader prairies than now cover the West. Alternations like these were again and again repeated, as geology has shown.

Through these means, the continent, which was begun at the far North, a region then tropical but afterwards to become inhospitable, gradually expanded southward, area after area as time moved on being added to the dry land.

First, as the facts show, the Silurian deposits of Canada and the North, adjoining the Azoic, were left above the sea, for these rocks there are not overlaid by later beds; and, therefore, were not the sea-bottom of later seas. Next, the adjacent Devonian were added to the main land as far south as Southern New York and around by the west; for, as the New York geologists have shown, the carboniferous beds which come next do not reach into that State. By the time of the Jurassic period, the continent had expanded much farther to the southward, for the carboniferous rocks over the land were out of water, their beds having already been folded up and elevated in the Appalachians. The red sandstone of the Connecticut Valley and of the Atlantic States from New York to Alabama leave little doubt as to the water-line of that era. In the Cretaceous period the continent had farther expanded along the Atlantic; but in the Mississippi Valley the Mexican Gulf still extended north even to the head waters of the Missouri. Next, as the Tertiary opened, the continent had yet more widely enlarged its bounds, south and south-east; and if the waters of the Mexican Gulf for a while claimed a place over some part of the Nebraska plains, as late observations suggest, by the close of the period the continent in this direction had nearly reached its full maturity. These steps of progress are indelibly marked in the position, and obvious sea-coast, off-shore, or estuary origin of the Jurassic, Cretaceous, and Tertiary beds of the country.

Passing towards the Pacific, we find evidence in the carboniferous limestone that the Rocky Mountains were mostly under shallow water as the Carboniferous age opened, the mountains themselves unborn. Later in the Cretaceous and Tertiary periods, as the rocks towards the coast testify, the continent had extended far to the south-west, and was nearly complete in that direction, as well as to the south and south-east.

Thus the enlargement went on to the southward, each period making

some addition to the mainland, as each year gives a layer of wood to the tree. Not that this addition was free from oscillations, causing submergences, for these continued long to occur; but the gain, on the whole, was a gain — a progress; and the moving ages made the accession a sure and permanent gain as the continent became more stable.

II. But in the statement that the growth of the continent was to the south, south-east, and south-west, we assert only the most general truth respecting it. The continent has its special features as much as any being of organic growth, and the elimination of these features is to be traced to the same system of forces. The Appalachian range on the east, the Rocky Mountains and the subordinate chains on the west, the lower lands and lakes of the interior, all in a systematic relation, are the more marked of these features; and the vast river systems, with the broad alluvial flats and terraced plains, the wide spread drift, the denuded heights and channelled slopes and lowlands, are subordinate peculiarities of the face of the continent.

The Appalachian range of heights, as I explained a year since, was commenced in the Silurian age, and even earlier long before a trace of the mountains had appeared.* The force from the south-east, in the dawn of the Palæozoic era, had made the Appalachian region generally shallower than the Mississippi Valley beyond. The vast sandstone and shale deposits of the region bear marks in many parts of sea-shore action, while the limestones which were forming contemporaneously farther west, indicate clearer and somewhat deeper seas; and the patch of Azoic in Northern New York, lying at the northern extremity of part of the range, points to an anterior stage in the same course of history; so that, in early time, long before there were mountains, the future of the continent, its low centre and high borders, was foreshadowed. We can hardly doubt that the region of the Rocky Mountains was in the same condition, in the main, with that of the Appalachians. Moreover, these borders, or at least the eastern, for ages anterior to the making of the mountains, were subject to vastly greater oscillations than the interior; for the Silurian and Devonian sandstones that occur along from New York to Alabama are of great thickness, being five times as thick as the limestones and associated deposits of

* Address, &c., see note page (9).

the same age to the west. A limestone bed, moreover, is of itself evidence of comparatively little oscillation of level during its progress.

We hence learn that in the evolution of the continental germ, after the appearance of the Azoic nucleus, there were two prominent lines of development; one along the Appalachian region, the other along the Rocky Mountain region — one, therefore, parallel with either ocean. Landward, beyond each of these developing areas, there was a great trough or channel of deeper ocean waters, separating either from the Azoic area.

The Azoic, as has been indicated, has something of a V shape, (or ⋁,) with Hudson Bay between its arms. This succeeding step of progress is the partial development of a larger V outside of and parallel to the Azoic nucleus. The channels alluded to lie between the two V's. The bar of the outer V on the left is of great breadth and made up of several broad parallel bands or ranges of elevations; that on the right is quite narrow comparatively, yet also etched in several parallel lines.

The Mexican Gulf is all that remains of the larger of these channels. Its waters once stretched to the Arctic Sea, and were in early time but the deeper part of the continental ocean. Later, as the ages moved on, there was land to the north, and a line of fresh-water lakes along its former course; and the gulf reached no higher than the head waters of the Missouri. Later still, and its limits became more contracted, till now the full-grown continent has but her foot in the salt water.

The Gulf of St. Lawrence marks the outlet of the other channel, and the River St. Lawrence its course. The great lakes, as well as the smaller lakes north, lie near the limits of the Azoic nucleus within these ancient troughs or depressions; and the largest lake, Lake Superior, is at the junction of the two lines.

Such was the law of growth. The molecular forces *beneath* the continent, from the progressive cooling there going on, were not idle, and must have modified the results. But the main action causing the lifting and sinking of the crust and the final gain to the land, proceeded from the directions of the oceans. The inequality in the forces from the two directions, as well as in the form and depth of each oceanic or subsiding area whence the forces mainly came, would necessarily have

produced many irregularities in the results, as I have remarked in another place,* and will not now dwell upon.

The Pacific region has always been true to its own grandeur. The force from that direction not only made the Rocky Mountains to rise and a file of lofty volcanoes to light up its waters, (while the most the gentler Atlantic could accomplish was a bending up of the strata into Appalachians, and a baking of some of the beds,) but it also added tenfold the most dry land to the continent; and even after the Tertiary rocks were deposited, it elevated the continental border at least two or three thousand feet, — ten times beyond what happened on the Atlantic side.†

But look further, and consider that the great lines of elevation on the Pacific side are parallel nearly to the islands of the ocean; that these islands are like a long train stretching off from Asia to the east-south-east; that New Hebrides, New Caledonia in the south-west, with the foot of the New Zealand boot and North-western Australia, conform to the general parallelism; and it will then be comprehended that we have been considering not simply a continental system of progress, but one involving the whole globe. It appears also from the history of the coral islands of the Pacific, that while the Tertiary and Post-tertiary elevations were going forward on the Pacific border of North America, a slow and gradual subsidence was in progress over a parallel region across the middle of the ocean. The axis line of the Pacific is not only the main trend of its lands, but is also nearly the course of the great subsidence which is indicated by the history of the coral islands.‡

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* Amer. Jour. Sci. [2], vol. iii.

† Whatever doubts may exist as to the cause, there can be none as to the actuality of the force on the two sides, the Atlantic and the Pacific. The elevation of the mountains on each border is proof beyond question; and their relative extent and height is evidence indubitable as to the relative amounts of force exerted. The parallel *folds* on the Atlantic side show that there it *was actually lateral* force from the south-east; and the several parallel ranges on the Pacific side, parallel to the ocean, are proofs of similar lateral action there, but from the south-west. Then the dominance of these two trends in the uplifts over the whole continent in its oldest and newest regions and rocks, are like the warp and woof of a fabric, determined by the organizing forces themselves of the structure.

‡ Amer. Jour. Sci. vol. xlv., (1843,) 131, and [2], iii. 396, (1847). One conse-

III. I have said that these two systems of forces — the south-east and south-west — continued to act through the Tertiary period, working out the continent, and bringing it nearly to its adult extent. At the meeting of this Association at Providence I pointed out the fact that at the close of the Tertiary there was a change in the movement; that during the following period, the Post-tertiary, there were high-latitude oscillations; and I endeavored to show, that there was first an elevation of the continent over the north for the first, or glacial epoch; then a subsidence (as shown by the sea-shore deposits on Lake Champlain, and the highest terrace of the lakes and rivers) during a second or Laurentian epoch; and finally, an elevation to its present height, for the third or Terrace epoch. Whether the elevation for the Drift epoch be admitted or not, all agree that the oscillation attending it was a northern phenomenon. These several changes thus affected mainly the latitudes north of the middle of the temperate zone, or were but slightly felt to the south of this. It is a remarkable fact that the coasts of the Arctic regions, which have now been rather widely explored, have not presented any Jurassic, Cretaceous, or Tertiary deposits, and there is, therefore, no evidence of their having been in those eras under water. Such beds may hereafter be detected; but the great fact will still remain, that they are there of limited extent, if not wholly absent. As far as known, there is no Tertiary on the coasts north of Cape Cod. All development or growth there seems to have ceased, or nearly so, with the Palæozoic era or the close of the Carboniferous age. But there are Post-tertiary deposits in the Arctic regions in many places, situated hundreds of feet above the sea, containing shells of existing Arctic species. This alone, independent of other evidence, would prove a change in the conditions of geological progress after the Tertiary period. The necessary inference is, then, that as long as the south-west and south-east forces were in active play,

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quence of these facts and principles may be here alluded to. If the position of the Atlantic and Pacific has determined the main directions of the organizing forces through all time, and if, owing to the direction, as the facts show, elevations having the *same* strike or trend have been formed in successive geological ages, it is evident that the elevation theory of mountains, sustained by Elie de Beaumont, must be received with much hesitation. One dial-plate for the world, such as he has deduced mainly from European geology, is a splendid hypothesis; but it may not mark time for America or the other continents.

and the extremities of the continent were thereby in process of growth, there was little change going on in the far north. But when the continent was nearly finished, its extremities grown, and the stability consequent upon adult age acquired, then, through a series of oscillations, a course of development was carried on in the more northern regions, giving a final completion to the continent — an action, which, as I have elsewhere explained, involved the higher latitudes about the whole sphere, north and south of the equator.*

We shall understand more definitely the relations of the later to the older oscillations, if we consider that all were due to one grand cause, influencing the whole extent of the continent even to the Arctic Ocean; that the force from the north, the south-east, and the south-west, according to the principle explained, was proportioned approximately to the sizes of the oceans, the Arctic, the Atlantic, and the Pacific; that the greater forces from the south-east and south-west acted against that from the north and through their superior strength or the concurrent greater flexibility of the crust, kept up those vibrations in the progress of which the border mountains were made; but at last, the south-east and south-west action almost ceasing through the stiffening and uplifting of the crust, then the northern force, having a stable fulcrum, made itself felt in the long and slow oscillations of the Post-tertiary. Under this mode of view it will be seen that all was part of one system of development.

If we rightly apprehend the results of the Post-tertiary period, we shall perceive that there was vast importance in these finishing operations over the sphere: — that during its progressing centuries, the great phenomena of the drift took place, covering hills and plains with earth; that the valleys for our rivers were then either made or vastly enlarged; that immense alluvial plains were spread out in terraces over the interior and in flats along the shores; that thus a large part of the brighter features of the globe were educed. The mountains of the earth at last stood at their full altitude, having gained some thousands of feet since the Tertiary; and rivers, true offspring of the mountains, taking their size from the size of the mountain ranges, were sent on renovating missions over the breadth of the continents. Indeed, the upper ter-

* Address, &c., loc. cit.

races of the rivers show that during the Post-tertiary, these interior waters had an extent and power vastly beyond what the streams now exhibit; — an extent which is yet unexplained, unless attributable, as I have suggested, to the declining snows of a glacier epoch. In their strength, they deeply channelled the hills, and wrought out much of the existing sublimity of mountain architecture. There was the elimination of beauty and of immediate utility in every stroke of those later waters, in marked contrast with the earlier operations of rock-making and mountain-lifting; for those very conditions, those special surface details, were developed, that were most essential to the pastoral and agricultural pursuits with which man was to commence his own development, while that grandeur was impressed on the earth that should tend to raise his soul above its surface.

This transfer of the process of development from the extremities to the more northern regions, thence evolving these new and more refined qualities of inorganic nature and humanizing the earth, has a parallel in organic growth; for the extremities are finished and adult size attained before the head and inner being are fully perfected. The analogy is fanciful; yet it is too obvious a parallelism to be left unsaid on that account.*

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* I have alluded on a former page to an analogy between the progress of the earth and that of a germ. In this, there is nothing fanciful; for there is a general law, as is now known, at the basis of all development, which is strikingly exhibited, as Professor Guyot has shown, even in the earth's physical progress. The law, as it has been recognized, is simply this: — Unity evolving multiplicity of parts through successive individualizations proceeding from the more fundamental onward; a law wrought out and developed, especially with regard to the inorganic history of the globe, by Professor Guyot. (See his Earth and Man.)

The earth in igneous fusion, had no more distinction of parts than a germ. Afterwards, the continents, while still beneath the waters, began to take shape. Then, as the seas deepened, the first dry land appeared, low, barren, and lifeless. Under slow intestine movements and the concurrent action of the enveloping waters, the dry land expanded, strata formed, and as these processes went on, mountains by degrees rose, each in its appointed place. Finally in the last stage of the development, the Alps and Pyrenees and other heights received their majestic dimensions and the continents were finished out to their very borders.

Again, as to the history of fresh waters. — The first waters were all salt, and the oceans one, the waters sweeping around the sphere in an almost unbroken tide. Fresh waters left their mark only in a rain-drop impression. Then the rising lands

Thus, then, the continent was completed. Contraction was the power, under Divine direction, which led to the oscillations of the crust, the varied successions in the strata, and the exuviations of the earth's life, era after era. Acting from the Atlantic and Pacific directions, it caused the southern prolongation of the growing land from the icy north to the tropics, while it raised mountains on the borders, and helped to spread the interior with plains, varied slopes, and lakes. And, finally, through its action over the north, the surface received its last touches, fitting it for a new age — the Age of Mind.

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2. On the Parallelism of the Rock Formations of Nova Scotia with those of other parts of America. By J. W. Dawson, A. M., F. G. S., &c.; Principal of the McGill College, Montreal.

The peninsula of Nova Scotia is occupied entirely by rocks of the Silurian, Devonian, and Carboniferous systems, and an overlying red sandstone series associated with beds of trap. It is especially remark-

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commenced to mark out the great seas, and the incipient continents were at times spread with fresh-water marshes into which rills were flowing from the slopes around. As the mountains enlarged, the rills changed to rivers, till at last the rivers also were of majestic extent, and the continents were throughout active with the busy streams, at work channelling mountains, spreading out plains, opening lines of communication, and distributing good everywhere.

Again, the first climates were all tropical. But when mountains and streams were attaining their growth, a diversity of climate, (essential to the full strength of the latter,) was gradually evolved, until winter had settled about the poles as well as the earth's loftier summits, leaving only a limited zone, — and that with many variations, — to perpetual summer.

The organic history of the earth, from its primal simplicity to the final diversity, is well known to exemplify in many ways the same great principle.

Thus the earth's features and functions were successively individualized: — first, the more fundamental qualities being evolved, and finally those myriad details in which its special characteristics, its magnificent perfection, and its great purpose of existence and fitness for duty, largely consist.

able for the great development and fine exposure of the carboniferous rocks, and for the circumstance, in part connected with the former, that all the formations older than the coal have been greatly fractured and metamorphosed before the carboniferous period, so that the coal rocks are quite unconformable to those of the Devonian period. I propose in this paper to give a general account of the latest state of our information as to the equivalency of geological changes and formations in this outlying portion of the American palæozoic and mesozoic formations, with those in the United States and Canada.

1. *Modern changes of level* in the western part of Nova Scotia, are evidenced by the occurrence of stumps of the pine and beech *in situ* at a depth of thirty feet below the level of the high tides in the upper part of the Bay of Fundy; and there are indications that the greater part of the marsh lands of that bay are based on such submerged upland. The observed evidence of this submergence depends on the great rise and fall of the tides of the bay, so that in other parts of the province similar subsidence may have occurred, without leaving the same traces. The best instance of a submerged forest in Nova Scotia, or perhaps in Eastern America, occurs near Fort Lawrence, and is described in the Proceedings of the Geological Society of London, for January, 1855.

This modern subsidence connects itself with that said to be in progress in the south of Newfoundland, and with the submarine forests that have been described by Professor Hitchcock, Mr. Gesner and others, as occurring in Prince Edward Island, the island of Grand Manan, and the coast of New England.

2. The Boulder formation is almost universally diffused in Nova Scotia, and, as in many other parts of the world, consists of two members, a boulder clay, indicating intense frost and continued subsidence, with ice drift of coast stones and boulders; and superficial gravels and sands, marking the action of the sea during the emergence of the country. Under the boulder clay the surface is generally polished and striated. No marine shells have been discovered, but in one place I have observed a bed of peat with roots of coniferous trees beneath the boulder clay; and in some other localities old stratified sands and gravels have been covered by it. Remains of mastodon have been found in the superficial gravel.

The distribution of boulders has been determined by currents by no

means uniform, and modified by the physical features of the country. The direction of the striæ and furrows is most frequently north-east and south-west, coinciding with that of the hills and valleys of the country, and with that of the present northern current of the coast, as well as with the prevailing course in other parts of the continent; but locally striæ are found to run east and west, and north and south, and there are often two sets crossing each other.

Boulders also appear to have been carried with almost equal facility in different directions. The central part of the province is overspread with granite boulders from the south and west, and with greenstone and syenite boulders from the Cobequid hills on the north and north-west. The Cobequids, elevated about twelve hundred feet, have on their northern ridges sandstone blocks from the plain of Cumberland, to the north, and on their southern slopes granite boulders from the south. The valley of Cornwallis and Annapolis, extending nearly south-east and north-west, has granite boulders from its south side carried across to the north, and trap boulders from the north carried up the hills on the south. Great masses of debris have been swept out of the ravines of the Cobequids to the south, while the ruins of the conglomerates of the Pictou hills have been swept to the north and north-east. When all the exceptions are taken into the account, the preponderance of northern drift is by no means decided, and in many localities is not appreciable.

No formation has been recognized in Nova Scotia between the Drift and a series of red sandstones, to which the name of New Red Sandstone has been provisionally applied, and which, at one time, were confounded with the more extensive and important red sandstones of the Carboniferous system, which these new red beds unconformably overlie. In Nova Scotia the red sandstone is interstratified with great beds of trap, tufa, and trap conglomerate. In the neighboring island of Prince Edward, where the formation is largely developed, these indications of volcanic action are almost entirely absent.

Regarding, for reasons which I have endeavored to explain elsewhere, the red colors of these sandstones as an indirect consequence of volcanic action, and having observed the association of red sandstone and trap to occur under precisely the same conditions, in the new red sandstone and the lower carboniferous series in Nova Scotia, and believing such association to occur in rocks of almost every geological age,

I do not attach much value to similarity of mineral character, as identifying these rocks with the red sandstones of Connecticut and other parts of the eastern States. In Nova Scotia, however, it is certain that this formation is newer than the Carboniferous system, and has accommodated itself to the surface arrangements effected at the close of the latter period. It enters in bays and inlets into the Carboniferous valleys, and in Prince Edward Island it extends across the ends of the carboniferous troughs of Nova Scotia.

No fossils have been found in the New Red of Nova Scotia; but in Prince Edward Island the large reptile described by Dr. Leidy, and named *Bathygnathus Borealis*, and the occurrence of araucarian coniferous wood and fragments of plants resembling calamites, perhaps point to a Permian date.

4. *The Carboniferous System* has a thickness certainly exceeding 15,000 feet, but in its horizontal extent it is limited by older ranges of hills, which divide it into troughs and basins, and have occasioned great varieties of structure in its different parts.

(1.) In Nova Scotia the coal formation presents an upward extension, which, in so far as I am aware, is not developed on the same scale in other parts of America.* It consists of several thousand feet of red sandstones and shales, with occasional gray beds, and fossil plants identical with those of the coal formation; but without workable coal or marine limestones. This portion of the series I have named in former papers the "Upper, or Newer Coal Formation."

(2.) The productive coal measures underlying this newer coal formation, in consequence of the local causes previously referred to, present us with three different types of structure.

(*a*) In some instances, as at the North Joggins and Sydney, a great number of beds of coal alternate with stigmaria underclays, sandstones containing erect trees, and shales and limestones with *modiolae*, *fish-scales*, and *cypris*. In such localities very frequent alternations of condition and elevation have occurred, and have been accompanied by a profuse vegetable growth. It is in coal measures of this type that we find preserved those erect forests, remains and footprints of reptiles, land shells, and impressions of rain marks, that have been described

* In the discussion a similar set of beds was said to occur in the coal field of Pennsylvania.

by Sir C. Lyell, Mr. Brown, and the writer, in the proceedings of the geological society of London.

(*b*) In one coal field, that of Pictou, the whole of the coal has been accumulated in a few enormous seams, included in black shales nearly destitute of sandstones and erect trees. The thickest of these great seams has afforded the skull of the largest known carboniferous batrachian (*Baphetes Planiceps, Owen*).

The special conditions of the Pictou measures appear to have been occasioned by a contemporaneous gravel beach, which has separated the Albion Mines area from those parts of the surface in which sand was being deposited alternately with the coal. (For details, see Journal of Geological Society, 1853.)

(*c*) Other parts of the coal measures present the aspect of the upper member of the series, already referred to, or that of the next lower member, without any extensive development of coal and its accompaniments. This condition appears to prevail more extensively in New Brunswick than in Nova Scotia.

Similar varieties of surface, during the coal period, have been observed in Great Britain, and even in the great coal areas of the Western States.

(3.) Below the coal measures we usually find a great thickness of gray and red sandstones comparatively barren of coal plants, and corresponding to the millstone grit of England, and perhaps, in part, to the lower carboniferous conglomerates of the Appalachian and western coal fields.

(4.) The next member of the formation in descending order, is that to which the name of gypsiferous series has been given. It consists of red sandstones and red and green marls, with thick limestones usually filled with marine fossils, and numerous beds of gypsum. This formation appears to be wanting in the north of the Appalachian coal fields, but is largely represented by the lower carboniferous limestones and gypsum of the west and south. It is also deserving of remark, that in Nova Scotia, where these lower carboniferous beds approach the older rocky ridges, the limestones are diminished or even disappear, and are replaced by enormous beds of conglomerate marking the ancient beach, on which pebbles accumulated instead of the limestones that were deposited in the deeper water; presenting an analogy on the small scale to similar facts observed over larger surfaces in the United States.

(5.) Near these ancient shores, and at the very base of the carboniferous system, there occurs a peculiar pseudo coal formation, consisting of dark and often calcareous shales and sandstones with coal plants; in one instance, a bed of erect trees, underclays, and very thin coals. It is also characterized locally by the presence of great numbers of scales of fishes. This deposit, which belongs to the bays and estuaries of the older carboniferous sea, has been recognized in many localities, and has, in former times, caused much confusion by its being mistaken for the coal measures, and consequently leading to the belief that the latter underlie the gypsiferous beds.

To this part of the carboniferous system I refer the remarkable bituminous fish-bearing shales of the Albert Mine in New Brunswick, which have been so fertile of litigation and controversy.

Similar deposits have, no doubt, been produced at the margins of all the lower carboniferous seas, though the peculiar local features of Nova Scotia were probably especially favorable to their development.*

The peculiar characteristics of the gypsiferous member of the lower carboniferous series in Nova Scotia, I believe to be due to igneous action proceeding on the margins of limited sea basins, in which great deposits of coral and shell limestone were being accumulated.

The remarkable similarity of the coal flora of Nova Scotia to that of the southern and western States and of England, has been often noticed. The marine fauna seems to be more closely allied to that of western Europe than to that of America; most of the more abundant and characteristic species, as the Productus Martini and Scoticus Spirifer Glaber, Terebratula Elongata, Ceriopora Spongites, and Fenestella Membranacea, being common European forms, while, in so far as I have been able to ascertain, few of the common species in Nova Scotia are identical with those of the western States. This would accord with the indications of separation afforded by the absence of the limestone from intervening portions of the American coal areas, and by the Devonian elevations of land in Eastern Canada and New England.

5. *Devonian and Silurian Rocks.* — Before the Lower Carbon-

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* In the discussion Professor Rogers and Mr. Lesley described a very similar lower or false coal formation as occurring in Pennsylvania and the South.

iferous period, great igneous disturbances had occurred in the area under consideration, and all the previous sediments had been fractured and baked, and had been in part elevated into rocky ridges and islands in which volcanic action was still in progress in the Carboniferous period.

Nothing lithologically equivalent to the old red sandstone has been found, but there are some hard sandstones and grits of uncertain age apparently underlying the coal formation, which may belong to this horizon. The first fossiliferous rocks seen in descending order, are a series of slates and hard shales with abundance of fossils and frequent calcareous bands, and in one portion a bed of fossiliferous iron ore. The disturbances and metamorphoses of these rocks are so general that it is difficult in this region to ascertain clearly the order of superpositions; but there is a very great thickness of beds, and Professor Hall supposes them to range between the Clinton and Oriskany sandstone groups of New York. I have, in the present summer, made surveys of some of the more interesting portions of this district, and collected many new fossils, which, however, have not as yet been examined. In some parts of these rocks, the general facies of organic life is remarkably like that of the English Upper Ludlow.

The chronology of the igneous masses which have penetrated these beds, is only as yet beginning to be understood. In one of the fossiliferous beds of New Canaan, about the horizon of the Niagara group, there are pebbles of Amygdaloidal trap, and associated with other neighboring beds there are interstratified green stones. These are the oldest igneous rocks that I know in Nova Scotia. The whole mass is then cut by dykes of greenstone and porphyry, and penetrated by great masses of white granite with black mica, precisely like that of the eastern townships of Canada and many parts of New England, and probably about the same age. This granite has penetrated vertical bands of these rocks, melting the edges into gneiss, but crossing the beds without interfering with their strike. I ascertained for the first time in the past summer, the Devonian age of the granite of Nova Scotia, by observing its penetration of beds at least of Upper Silurian if not of Lower Devonian age; and collected many curious details in reference to the junction rocks, which I hope to throw into form for publication in the course of the winter. Lastly, the rocks of this group have been again penetrated by trappean rocks which have over-

flowed among the Lower carboniferous conglomerates; and probably, also, in a few instances by the trap of the New Red Sandstone.

The older Silurian rocks of Nova Scotia are represented by an enormous thickness of gray quartzite and clay slate in very thick bands, occasionally passing in the vicinity of the granitic masses which have been forced through them into mica, schist, and gneiss. These rocks have not afforded any fossils, and seem to be quite destitute of calcareous matter. They may, perhaps, be taken as representatives of the arenaceous and argillaceous members of the Lower Silurian series, without the limestones. They form, with the intrusive granite, a broad belt along the Atlantic coast of the province; and all igneous action appears to have ceased in this belt before the close of the Devonian period; a circumstance in which these rocks differ from the Upper Silurian and Devonian series already described.

The altered rocks which I have supposed to be Lower Silurian, are very destitute of calcareous, magnesian, and metallic minerals; with the single exception of iron pyrites. Those which appear to be Upper Silurian, on the contrary, contain much calcareous matter in thin bands, interstratified peroxide of iron with fossil shells, and large veins containing ferruginous dolomites, spathose iron, specular iron, and sulphurets of copper. We do not appear to have any representatives of the great Silurian limestones of the United States and Canada, though these occur on a large scale at no greater distance than the neighboring Province of New Brunswick.

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3. Geological Observations on the Pluto-volcanic Slope of the Sierra Madre along the Azimuth Boundary Line through North-west Sonora, made under the direction, and communicated with the permission of the United States Commissioner, Major W. H. Emory, U. S. A. By Arthur Schott, of Washington, D. C.

An air line drawn south-eastward from a point on the left bank of the Rio Colorado del Oeste, twenty miles below the mouth of the Gila to

the intersection of the meridian of 111° W. longitude from Greenwich, and the parallel 31° 20′ north latitude, comprises that western portion of the new boundary between the two Republics of the United States and Mexico, which was lately surveyed and established under the provisions of the so-called "Gadsden Treaty." Geographical terms for the same section of boundary line would be "Sonorian" or "Pimerian" line, for it runs through that north-western part of Sonora, which bears also the old Spanish name "Pimeria Alta," that is, "High Pimeria." A geodetic name for the same stretch of line would be "Azimuth line," because it intersects in an oblique direction from south-east towards north-west all the meridians and parallels falling in with it.

This line distinguishes itself from the eastern portion, which, running parallel to meridians and parallels of latitude, crosses north-eastern Sonora and Chihuahua, and finally terminates on the banks of the Bravo del Norte, a little above El Paso del Norte.

Our Azimuth line, then, takes its course, for its entire length, over the eastern slope of the basin of the California Gulf, following there the *divortia aquarum* between the Gila and those streams of North-western Sonora, which, by a south-westerly course, drain the adjacent country, finally shedding their water into the gulf just mentioned.

From one extremity of the line to the other, that is, from the heights of the Sierra del Pajarito, in the upper part of the Santa Cruz River valley, to the initial point on the banks of the Colorado, the line measures 233 miles (round number).

As to figures expressing the relative value of the hypsometrical features of the country, we shall have to be content with but approximative numbers, for circumstances have prevented actual measurements to that purpose.

An imaginary line drawn from the most elevated point of the Sierra del Pajarito about 200 or 300 yards south from the eastern terminus of the line to the initial point on the Colorado, exhibits a dip of about 22.1 feet to one mile, or an equivalent of 0.41 to 100. The point of elevation of the before-named Sierra is supposed to be 5,000 feet above the waters of the Colorado next to the initial point. Adding the difference between this point and the level of the sea, the elevation of the Sierra del Pajarito may be put down at 5,180 feet. This point does not seem to reach the pine region, which, in these latitudes, may be considered as from about 5,500 to 6,000 feet above the ocean.

The surface of North-west Sonora is characterized by a monotonous simplicity of features, and if it were not for close examination, even a more scrupulous observer would not be able to discover any thing but a mere dualism of diluvial drift and pluto-volcanic masses of rocks and mountains.

Along a very considerable portion of the line the former has covered those mountain ranges almost to their top, especially those approaching the valley of the Colorado. In reality the western section of our Azimuth line is running over what may properly be styled "a veiled country;" for of mountains only the crests and summits are to be seen, occasionally budding out from those desolate sand flats, which have buried the valley of the lower Colorado. This river winds its course through these forsaken barrens of drifting sand like a serpentine oasis, bordered by comparatively but narrow strips of timbered bottom-land.

The mountains ranging across that drift form the skeleton or frame of the geological edifice of the country, whilst the diluvial main may be looked on as its sinew and muscle. If we go further in the comparison, the alluvial deposits may be called the tegument or epidermis of the whole, which, to be sure, is most poorly represented. This natural deficiency, however, facilitates the observations of the geologist, who may look upon this country as if it were prepared and laid open for analytic investigation.

As its uppermost stratum we first take sight of the alluvials, of which very little is met with over the whole country except at the extremities of the line. The larger share of it appears in the bottom-lands of the Colorado; next to these come the regions of the higher mountains, whilst, strange to say, the plains are in this respect last in order.

The slopes, and generally the more or less inclined planes on the mountains, are sufficiently rugged and rough to form crevices, dells, and small valleys with obstructed outlets, which prevent entire deprivation of alluvial deposits, and form a condition of primary importance for the development of vegetable life, of which the almost naked plains, suffering under the sway of climatic severities and the devastating sweep of an almost continually moving sand, are a sad specimen.

Few traces of alluvial soil may be looked for at the so-called "playas" in the plains. These are depressions in the ground either sunk or washed out, and at the greatest vertical distance from the

summits of the mountains. Into these basins the aqueous deposits of the atmosphere, together with the lighter particles of the surrounding soil, are carried. In many cases the traveller may find here vegetation more developed, which then, however, consists more of a mass of equals than a diversity of genera and species.

Frequently such an apparently premature attempt of nature to promote vegetable life is sadly counterbalanced by the saline character of the soil, and then a prevalence of corresponding forms, as *Obione*, *Salsola*, *Salicornia*, and others analogous to them, take the place of *Algarobia*, *Prosopis*, or even of *Salix* in corresponding places.

The mainland filling up the levels between the various mountain ranges is constituted of a more or less uniform deposit of loose diluvial sand, a compound not essentially differing from the material the mountains are composed of. So we may call it, without hesitation, the detritus of the adjacent mountains, and the underlying firmer parts of the land. As to the mode of its being formed and distributed, we firmly believe it to be the residue of a once intermediate ocean, at the time a combining link of the Atlantic and Pacific Oceans.

Changes in the composition of this deposit certainly occur, but they appear to be more of a local character, and a certain uniformity pervades the whole. Fragments of quartz, mica, felspar, and of other crystalline and igneous rocks, together with particles of lime compose this almost unbounded stratum, forming a vast region of deserts between the eastern foot of the Californian cordilleras and the table-lands bordering the eastern shore of the Bravo del Norte. So we look upon it as a diluvial ocean a thousand times intersected and protruded by those gigantic walls, dykes, and reefs, which we know to be those mountain ranges already mentioned.

In the immediate vicinity of the latter, banks and isolated beds of pebbles are visible, the character of which is analogous to the lithological features of those mountain parts, whence they are derived. These pebbles, however, are not be confounded with other similar looking pebble banks, which appear occasionally right in the centre of those desert basins, especially along certain water beds, which at present may have served out their purpose, or may still be the dry channels for passing off rain-water currents.

Pebble beds of the first order are the result of the disintegrating agencies of the atmosphere upon the faces of the mountains, and are

deposited not far from the place whence they originated, whilst those of the second order seem to be the gatherings of an immense area, consisting of different pieces, removed from most diverse and often very remote geographical quarters. A wide-spreading medium must have gathered a compound of so heterogeneous constituents. In these sand beds we find, for instance, in loose pieces, limestones of different age and thrown together, where almost every geological era is represented by from carboniferous up to fresh-water forms. We also find here all kinds of opal, chalcedony, agate, jasper, slates, and other siliceous and silicified forms, breccias, conglomerates, either crystalline or amorphous. There are placed together silicified, agatized, or opalized fragments of wood, side by side with mere incrustations, either metamorphic or unchanged, and quite of late date. On another spot we may observe a semiopal, consisting entirely of fossil shells, the age of which is readily recognized by numerous Nummulites associated with them. With the hand we may take up an agate abounding in the neatest fragments of encrinitic or coralline forms, whilst our foot touches pieces of jasper or hornstone, in which, by means of a common glass lens, grain and texture of some coniferous wood can be perceived. Not uncommon are also large fragments of wood opal, also exhibiting ligneous texture, though with the traces of granulation entirely vanished away. Also glass opal or hyalite containing casts and marks of coralline forms; or pisolites, either unchanged or metamorphic, as if indicating the making of a loadstone.

The deserts on both sides of the Colorado and along the Gila abound in such pebble beds, surrounded by that same above-described uniform sand, by which they become occasionally entirely buried, or from under which they are redeemed again by the play of the atmospheric currents.

For the scientific observer, fragments of the mentioned character are the pearls of this vast terrestrial ocean, which must have formed once the bottom of an aqueous waste of the same dimensions, and under the sway of which these pebble beds must have been collected. Since the waters have receded from this area, another ocean of more substantial nature is waving here. Now the aerial currents are driving the shifting sand about, as it once moved with the waves of the ocean. At present only local alterations take place, moving the sand from one place to another. The level of these deserts must undoubtedly have been dis-

turbed since they were deposited. Besides the general declination of the western slope of the Sierra Madre towards the Gulf of California, an increased declination of stratum, round the base of intercepting mountains, is visible. This deviation from the angle of general ascent from the Colorado towards the Sierra Madre does not affect the mean angle of declination, which the diluvial main exhibits, but we may ascribe the former solely to the deposition of debris from the mountains.

The angle formed by the rising of the diluvial deposits and the base of the mountains in the Santa Cruz River valley, at the foot of the Sierra Santa Rita, was found to be $= 2.5°$.

The general ascent of country is a more essential proof of the upheaving of the country since the deposition of the quaternary strata or the diluvial drift. A line placed upon its plane, from the valley of the Colorado to that point of the Sierra del Pajarito where diluvial deposits cease, that is, about 1,100 feet below the highest point of elevation of said sierra, rises to about 3,900 feet, which makes 12.44 feet per mile, or an equivalent of 0.23 to 100.

Some valleys may exist heading on the slopes of the Sierra del Pajarito, through which diluvial deposits are rising still higher, but such exceptions do not affect the average of general ascent. The relative and absolute elevation to which this diluvial main rises in its approach to the Sierra Madre, forms a striking peculiarity in the features of the country. With a gradual ascent it furnishes a natural bridge almost over the whole height of those rocky mountains, the rugged crests of which otherwise would have remained inaccessible. Whilst offering, however, such an advantage to man's purposes on one side, it involves on the other side very serious evils. For it covers like a thick veil all that portion of country, which for its level character, or at least for its very small declivity, should form the proper field for those higher faculties of nature by which vegetable and subsequently animal life is developed. Instead of that, however, it now lies prostrated, a geological Sisyphus, having water at its base, and seeing water treasured up in the clouds without being able to receive and appropriate it. Even those few rains falling during a short season upon it are instantly swallowed up by the bottomless sand, leaving no marks of having been any way beneficial.

The few periodical water streams descending from the rugged mountain slopes, share the same fate with the scanty gatherings of the

clouds falling upon this drift land. Immediately after reaching it, they disappear from the surface, sinking to unknown depths, leaving marks of a rudimentary drainage only in the nearest vicinity of the mountains. Here bunches of shrubbery and trees border the usually dry water beds of the country. The blessings of water are lost upon these plains almost entirely, like ill-trusted alms in the bottomless pocket of an unworthy beggar.

The vegetation peculiar to the surface of this desert is much like that of corresponding localities on the east slope of the Sierra Madre. Besides a number of smaller and more inconspicuous forms, the *Larrea Mexicana*, *Fouquiera spinosa*, several *Obiones*, and other chenopodiaceous shrubs, and quite a number of papilionaceous and mimosaceous herbs, shrubs, and trees, together with various members of Cactaceæ occur through these desert regions, familiar to every traveller who has once passed over these plains.

We pointed above to the simple plan upon which nature has constructed the firmer parts of the country, that is, its rocky frame or skeleton. To come to the underlying strata upon which the diluvial deposits are placed, we have to step very deep at once, for constituents of the secondary era seem to be lacking wholly. Crystalline rocks of primary and transition age, metamorphic and unaltered, form the vast bed upon which the upper strata are placed. This foundation, however, does not form an even plane varying in its inclination, but its surface appears manifoldly broken, protruded, and turned up by eruptive masses, thus rising in many places above the level of the diluvial plains. The mighty sierras now forming the skeleton of our geological edifice have been shaped in the same way. In regard to their petrographic character we may distinguish them as pluto-volcanic.

With the hypsometric features of these mountain ranges, three important characteristics are connected. These are: 1. Parallelism among themselves, and also congruity of bearing to the range of the western coasts; 2. Articulation; and 3. Petrographic uniformity.

The parallelism among the various mountain ranges, and also the striking reference of their bearing to the western coast, is a fact much better known than the laws under which nature has effected it. Whether the linear extension of the longitudinal axis of these mountains was caused by a combined action of electro-magnetic forces and the tidal oscillations of the oceans, influenced and modified by isother-

mal, isoclinic, and isodynamic currents, we are not able to decide, and so we offer the following, though a mere theory founded upon observations made on the spot. Perhaps after the first onset of that peculiar reef, or dyke formation, probably a primary response of volcanic forces to the action of positive and negative electro-magnetism, a preliminary deposition of crystalline primary and transition rocks took place, followed by the precipitation of sedimentary strata. At this time igneous forces no doubt prevailed, and therefore the order of strata are throughout either of crystalline or of compact lava-like character.

In the course of those events the increasing volcanic debris became one of the agents to limit the heretofore free power of volcanic forces, promoting the counter actions of aqueous forces. Exogenous growth increased, whilst endogenous outcrops became confined. The waters, with their sediment, commenced locking up the volcanic fissures, whilst the fires had to seek other outlets, at the same time combining with their vertical vibrations horizontal oscillatory motions. To this we may ascribe the formation of those long reef and dyke-like mountain ranges, perhaps orographical meridians, which appear, however, often abruptly intercepted by cross valleys, dykes, or reefs, formed by different rocks. Such articulation may have been conditioned by the natural divisions of strata, that is to say, stratification, clearage, and lamination, influenced again by the aqueous interoceanic currents, which must have acted powerfully before all the walls separating the Pacific and Atlantic now were entirely closed. Considering such mode of formation, we cannot wonder at the diversified combination of plutonic, volcanic, and neptunic rocks, as they are in fact represented in the orographical system along our Azimuth line. We also cannot be surprised in perceiving the close petrographic relationship existing between all the different sierras, because they rose altogether from one pluto-volcanic focus, and were formed very likely surrounded by one general medium that was in a state of submersion.

To what degree our theory may agree with the geological data actually seen and observed, a special survey of the mountain ranges along our Azimuth line may show. Before entering, however, upon this subject, we propose a few remarks on some Spanish terms, which identify their objects with so much precision, that we should not like to part with them, lest we should be compelled to use insufficient circumlocutory words in their place.

We refer, then, to the following words: *Cordillera*, *Sierra*, *Cuchillo*, *Picacho*, *Puerto*, *Cañon*, *Loma*, *Mesa*, *Ciénaga*, *Charco*, and *Tinaja*.

Cordillera means a long mountain range composed of several parallel running integrating ranges, which, however, occasionally can be intersected by cross valleys and passes. The characteristic of the term is, that a cordillera is formed by two or more ranges constituting one orographical body, as a cord consists of several strings twisted together. Cordillera and cord are formed upon one root.

Sierra means a saw, or a mountain range with a serrate crest, and of a reef, dyke, or wall-shape. The cross diameter of both the Sierra and the Cordillera is generally very small, compared with their longitudinal axis.

Cuchilla is a branch or outrunner of a sierra, partaking in its physiography with the latter. Its sharp-edged crest probably caused the name Cuchilla, which stands upon the same root with cuchillo, signifying knife.

Picacho signifies a sharp, tapering, or obelisk-like peak, with the cross and long diameter in a similar disproportion as for a Sierra or Cordillera.

Puerto, a gate, gap, or port. Its topographical meaning here is, an open pass over or through a mountain ridge, not of any length, as in, for instance, a causeway or *cañon*.

Cañon is a mountain pass or defilée with no outlets on either side.

Loma is a long narrow mountain or hill-ridge, with a level horizon; Lomita is but the diminutive form of it.

Mesa table means here table-mountain or table-ridge, the top of which is of a wide horizontal extent; mesilla is the same on a smaller scale.

Mal páis. Bad land or *mauvais terre* of the French. In Sonora it is exclusively applied to mesas, lomas, or any table-land constituted of large beds of igneous rock mostly compact or vesicular black trap.

Ciénaga is a valley or mountain basin with an obstructed outlet and hemmed in all round by hills or mountains; thus the ciénaga abounds in miry or swampy places.

Charco, a water-pool found usually in lower and level places. They are formed either by the decay of rocks or by washing out of beds of clay.

Tinaja, a water-hole in solid rock, and usually met with in the crevices and ravines of rocky mountains. The word applies originally to an earthen jar not glazed so as to allow exudation of the contents, by which means the water inside remains cool.

After this we may proceed with a review of the various sierras, which, by following our Azimuth line from south-east to north-west, we shall have to cross.

The eastern terminus of our Azimuth line on the north slope of the Sierra del Pajarito shows crystalline transition rock either metamorphic or unchanged, and also trachytic and porphyritic strata or else metamorphic forms of granite and syenite. Some of the more elevated parts exhibit very rough masses of a cellular texture, whilst the lower are more solid and smooth in the water beds, even polished. The color is dull red or subdued light pink. These rocks also abound in crystals of glassy felspar, and occasionally particles of augite, thus answering to the frequent occurrence of syenitic granite. The foot of this sierra is on the north side washed by a small mountain stream, which is, however, during the most part of the season dry, with the exception of few *charcos* and *tinajas*, which are formed in solid masses of rock. The bed of this little stream is lined with a singular formation, apparently of later age. At first sight we looked upon it as if it were fresh-water lime overlying or placed alternately with a certain volcanic breccia, the matrix of which is much like the just mentioned formation. Perhaps it is really a volcanic mortar, in which large and angular fragments of amygdaloid and porphyritic rocks are imbedded. This same compound forms throughout the lower portion of the beforementioned valley one solid cemented mass, hemming in *cañon*-like the course of a torrent between vertical walls of an average height of 30 to 50 feet. The color of these masses is a brownish yellow, with an ash gray crust. The latter looks as if it were the result of a process of calcination. In some spots where this crust was found decaying out, a marl-like, mealy powder, like chalk, could be scratched out from the inside. Upon further investigation, also, trappitic, amygdaloid, and porphyritic rocks, at whatever elevation they had been taken up, were found with a cream or mortar-like paste of carbonate of lime adhering to them or filling the otherwise empty cavities of vesicular or else porous, igneous rocks. From this we conclude that carbonate of lime, in some form, must have been an ingredient in the formation of this strata of

later date. In the east slope of the Sierra del Pajarito, in a valley called "Los Nogales" (the walnuts), similar strata border the course of a little stream on one side forming a continuing winding low bank or terrace from six to ten feet high, exhibiting horizontal stratification, and on the other side covering, to some extent, the slopes of the surrounding mountains and hills, constituted of crystalline transition rocks. On these hill-sides these apparent limestone strata form shelve-like beds coating over those rocks of higher age. These shelves are dipping towards the valley. Their texture shows plainly lamination. Further east from Los Nogales, that is, in the Santa Cruz River valley, the same formation seems to be still more boldly developed. To the south and towards the south-easternmost link, the same Cordillera that is on the strike side of the Sierra Santa Barbara, and also still further down into Sonora, strata of the same nature abound through all the valleys drained by running water.

The volcanic breccia, occurring also and in abundance in most of those water-leading valleys and ravines of the Sierra del Pajarito, rises from forty to fifty feet under an angle from upwards of 45° to vertical walls. Some pieces of this mass were tried, heated in a large log fire, and then thrown into cold water, upon which they showed much effervescence, but without going to pieces.

To the north and north-west of this mountain range, with its bearing from east to west, the Sierra Janos is rising up in bold terraces of a dark-red brown amygdaloid trap, or trap-porphyry. The broadest terraces are along its lower regions. The edge of each of these gigantic shelves is bordered with outstanding rocks, reefs, dykes, pinnacles, cliffs, in the most fantastic manner. The level of the terraces declines towards the main body of the sierra; thus a series of parallel running lateral sierras are formed. The most elevated part, the central stock, forms a huge table-block, exhibiting on its south and west side distinct marks of stratification, cleavage, and lamination. These marks intersect each other vertically, and so the whole mass resembles a veritable mason-work, the rectilinear fissures of which are visible at a distance of from ten to fifteen miles. The vernacular name, "Janos," has thus as little to do with the physiography of these mountains, as Pajarito has with the former. The one means a little bird, the other a certain shrub. The latter may have some physical reference to the sierra to which this name is fixed. Janos signifies in the Papago language a species

of chilopsis, which grows in superabundance, in analogous localities, all over those regions. The striking resemblance of the central block of this sierra to mason-work, would certainly justify the repetition of the more appropriate name, "de los ladrillos," (of the bricks,) for it agrees in its appearance with the description of a portion of the Peruvian volcano Pichincha, given by Humboldt. A similar petrographic phenomenon is mentioned there, with the only difference, that the rock on the Peruvian mountain consists of some kind of pitchstone-cleaving ore, laminated in its vertical slabs or layers. This makes the strata, at a distance, appear like mason-work, and gave rise to the name, "de los ladrillos," among the inhabitants of Quito.

On the northern foot of the Sierra Janos, another group, though upon the same longitudinal axis, is annexed, forming clearly with both the former one body or one sierra, ranging south-east and north-west, and bordering the left bank of the Santa Cruz River. The three links of this sierra have a common dip and strike; the former being in an easterly direction, and on the sierras Janos and Atascosa from 5° upwards to 25°; the latter faces the westerly regions, and falls off vertically, in bold terraces. The petrographic character of the Sierra Atascosa seems to fall close together with that of the Janos, and as they are also so closely connected, they may be considered as twins. The mountain range formed of these three sierras terminates on the north-western slope of the latter, where a valley intersects an immediate connection with the Sierra del Babuquibari in the north-west. This valley, communicating on the east side only by a narrow pass with the valley of the Santa Cruz River, is one of those intersections separating the cordilleras and sierras of the country into articulated mountain bodies. The valley itself bears the name of Aribac, or Aribaca, from a deserted Mexican settlement, situated there. Good and constant spring water is found here, which may cause sometime the reëstablishment of the rancho, after security against the marauding Apaches shall be realized. The name "Aribac" is undoubtedly of Papago origin, though we could not ascertain its meaning. The slope of the Sierra Atascosa, towards this valley, is formed by igneous rocks and peaks, towering up in the most odd and grotesque shape. This locality also bears the name "Mal pais," which it certainly deserves, considering the rugged character of this slope of igneous rocks. Atascosa, the name referring to the whole of this sierra, means, "miry,"

or "stick in the mire." We know not whether this name really points to the petrographic character of these mountains, which is indeed most likely, because they appear as if they had once risen out of a boiling volcanic pool during some chaotic era.

The absolute height of these three sierras above the level of the Santa Cruz River seems to be pretty nearly equal, though the highest points of the Sierra Janos looked to me as if they commanded all others.

All round the Sierra del Pajarito smaller and larger springs abound, but their course is more or less concealed, and it wants, therefore, the expert eye of an Indian, Mexican, or hunter to find them, especially during the latter part of the dry season, that is, from April to a part of July. On all sides of this sierra, from its base to the summit, vegetation is well developed. All the slopes and valleys abound in good grazing, and a dense growth of shrubbery and trees covers the rough surface of those mighty slopes, cut up into thousands of little valleys, ravines, and crevices. Three or four different evergreen oaks are met with on this sierra, among them the "vellote" of the Sonorians, with sweet, eatable acorns. A species of cedar appears in the more elevated parts, which, however, does not seem to reach the pine region fully. A few years ago the fauna of this country was characterized by hundreds of heads of wild cattle roaming through these grassy valleys, but they have since been exterminated by the restless hunter. According to its physiographical features the Sierra del Pajarito partakes in the good things of the Sierra di Santa Cruz, and all the various links of those sierras belonging to one system with the Sierra Madre, farther east. Even in respect to metals the Sierra del Pajarito is not left behind. Whilst in camp at "Los Nogales," Major W. H. Emory, United States Commissioner, received several fine pieces of very promising looking silver ore, obtained in the immediate neighborhood of that place.

On the top of the Sierra del Pajarito we find ourselves on the vertex of a dividing ridge, sending water by the Santa Cruz River north-west to the Gila, and south-west towards Presidio del Altar, and other places in that direction. We have dwelt, intentionally, longer upon the features of this sierra, because of its being hypsometrically and geognostically best developed among all the sierras coming to sight hence west towards the Gulf of California.

The Sierra del Pajarito forms a type and a standard for the comparative review of the rest.

Viewing the country towards the gulf from the western peaks of the Sierra del Pajarito, a wild and rugged net of mountains lies spread out. Notwithstanding their being constituted of similar crystalline and transition rocks, they do not rise so high as the former, but being in long ridges, closely packed together, and dipping uniformly towards the south-west, they form a kind of mountain relief, the grandeur of which lies more in its uniform wide extension, than in the peculiarity of shape.

At a distance of about sixteen miles another sierra of igneous rocks is visible. Between this and the last one we spoke of very little drift is met with, and, where it appears, we find it always confined to valleys, until we come half way between both sierras. Here, by the action of water currents, *mesas* and *lomas* have been formed, rising to the height of from 40 to 50 feet.

The waters running from here south-east soon join those coming from the east slope of the Sierra Escondida, a small distance south of the line, near a place where in a hidden deep cleft between igneous amygdaloid rocks permanent water is found. This, however, seems not to be a spring, but a *tinaja* supplied by the trickling down of water from *tinajas* situated above. The character of this place caused the name "Escondida," meaning here the concealed water, but it is applied to the whole sierra. This range, according to its orography, is but a gigantic volcanic dyke, here towering up with an isolated rugged crest of igneous rocks (amygdaloid and porphyritic), and there intercepted or overlaid by overthrown and contorted crystalline strata of a coarse-grained felspathic sienite, mostly metamorphous. The cross diameter of this sierra, where it is intersected by our Azimuth line, exceeds scarcely one mile in length. It is, however, on both sides bordered by the quaquaversal upheavings of those crystalline beds just mentioned.

Near the spot, where three singularly looking peaks mark the locality of that hidden *tinaja*, we visited the top of the sierra, which, in barrenness, far surpasses the Sierras Pajarito, Janos, and Atascosa. Some parts of the table-like planes and also the slopes are covered with large patches of white chalcedony in the shape of scoria. The southern part of this sierra exhibits a more horizontal arrangement, as

if its disposition had been made in a state of submersion. Here black vesicular trap prevails, forming ridges and cross banks, and further below, *lomas* and *mesas*. The topography of the country seems to indicate here the junction and gathering-place of a number of mountain streams and torrents.

The boundary line crossing the Sierra Escondida, passes over its crest a little to the north of a conspicuous peak, the highest point of the whole range. This peak, belonging to the State of Sonora, received, therefore, the boundary name "El Cerro di Sonora."

A group of low granitic hills, a western upheaval of the Sierra Escondida, furnishes, near the line, several water places well known to the natives of the country, the Papago Indians, Mexicans, and Apaches. Some of them are mere *tinajas* and *charcos*, others seem to be real springs. They are liable to become sometimes dry before the setting in of the rainy season. A heavy hail and thunder-storm our party encountered here occasioned the name "del granizo" for this little mountain group. This same meteoric incident furnished a proof how little time it requires to submerge all the adjacent valleys under the most terrible sweep of mountain torrents. Our camp at the time was near the head of a ravine, and, notwithstanding the short range of the latter, after an elapse of not more than five minutes hail and rain had created a water current of at least five feet average depth, thus instantly filling up the whole rocky bed to its top. The granite found on this sierrita is white, very coarse grained, and richly charged with large plates of silvery mica. It is also occasionally impregnated with an addition of hornblende.

A broad, flat valley nine miles wide separates the Sierras Escondida and Granizo from the Sierra Verde, which is nothing more nor less than a southern spur or branch of the Sierra Babuquíbari to the north of the line. The plains bordering the various dry water beds of this valley are well furnished with good grass, and seem to be the resort of plenty of game. The water beds themselves are bordered by a remarkably rich growth of oak and hackberry (Altis). The Sierra Verde, so called from the beautiful verdure encountered in the shelter of its rugged and clefted valleys, seems to be formed entirely by the same felspathic granite, which was mentioned for the east slope of the Sierra Escondida. The dip and strike face East and West. The width of the sierra is scarcely more than one mile, and no petrographic

novelties are here met with. Its longitudinal axis ranges south-east and north-west, where it joins the bold igneous walls of the Sierra Babuquſbari, at a distance of about fifteen miles hence. The entire length of the Sierra Verde scarcely exceeds twenty miles. Round its southern end some trappitic hills and mounds cross out from the diluvial main. At the same locality, right under the steep side of the sierra, a springs finds its way to the surface, fitting this place for a general camping-ground for roaming Indians or travelling Mexicans. The locality itself is generally known to the inhabitants of the country under the name "Pozo Verde," (green well).

Almost due north from the surveying station established upon the crest of the Sierra Verde the *Picacho* of the Sierra Babuquſbari is situated. This is one of those orographical phenomena of the country, the singularity of which could not fail to raise the attention of the red man. The Papago Indians in fact consider this large mountain obelisk their palladium, where they take refuge in times of famine, drought, war, or any other general calamity. "Babuquſbari," we were told, signifies in the language of these Indians, "water on the mountain," and is formed by "babu" water and "ari" rock or mountain.

The increased height of the main body of this sierra, and especially the bold offset of a large obelisk of one solid mass on the top of the former, exercise, very probably, an increased power of attraction upon the clouds, which, therefore, gather more copiously round its head. At the same time the more inaccessible recesses of the sierra aid the securing of welcome water stores in those higher regions.

Viewing the country westward from the heights of the Sierra Verde another wide plain is visible, which, at a distance of from twelve to fifteen miles, is intersected by another mountain range, traversing the country in that invariable bearing, south-east and north-west. The eastern half of this intermediate plain seems to be more favorable to the development of vegetation than the western part, which, especially in its lower portions, is entirely deprived of floral life. The eastern part abounds in grass and dense brush-work, besides a considerable growth of mosquito-wood, whilst the western seems to have been at first divested of all vegetables by the destroying tooth of small troglodytic quadrupeds. It is a singular fact that both parts of this plain, a short time before our visit there, had been equally benefited by copious rain, and notwithstanding the western half had remained a naked, barren

flat. Through the thickets of the slope under the Sierra Verde we saw flocks of black-tailed deer, which seem to have here their western limits, whilst, on the western barren half, numbers of shy antelopes freely ranged over the open level. No doubt the physiography of the country commences here to change to its disadvantage, of which we shall see more after reaching the next mountain range; which, unlike the others passed until now, is but a short detached group of hills and mountains budding out from the diluvial main like an island. Though of much smaller extent, it still presents the same petrographic character by being a binary compound of igneous and crystalline rocks, the latter taking, we believe, the larger portion. On the east slope similar felspathic granite rocks in a decayed somewhat metamorphic state occur, whilst the west slope exhibits again that quartzose quaternary granite we spoke of at the Sierrita del Granizo. The centre part, the spine of the whole, is formed by amygdaloid and porphyritic masses here and there overlaid or otherwise concealed by crystalline strata, which have not been thoroughly protruded by the former. The north part of this sierra is occupied by the highest peak, rising solitary above the others. This fall to the north of the boundary line received the name "Cerro de la Union," which was also applied to the whole group. From the surveying station established in the *puerto* of the Sierra de la Union, we look east and west as from a physiographical dividing ridge upon the surrounding country.

Through the part just passed over, mountains and mountain stretches prevailed, leaving but a small share for the distribution of diluvial deposits, but hence westward levels and plains, formed by drifting sand, increase and consequently sterility and desolation become a ruling feature. This change seems to be caused by the gradual submersion of the mountain ranges under the level of the diluvial main. Thus losing width and length, sierras appear now but as interrupted detached parts of mountain ranges, the mutual connection of which only can be guessed at by their general geographical bearing. Cordilleras and sierras, as we shall see afterwards, are of a more loose texture from the increased interspersion of drift land. Whilst the country to the east resembles an aggregate of narrow straits bordered by long mountain reefs, the land ahead begins to widen and become like the outside of a shallow coast, studded all over with small rocky islands and cliffs, the scattered pieces of reefs and dykes. The more open country

is now influenced by the climate of the gulf coast. Certain plants, apparently real desert forms, appear first on the west slope of the Sierra de la Union; among them two leguminous trees, the *Palo Verde* and *Palo di Hierro* of the Mexican. We notice here, also, a predominance of cacti, which we may not improperly call the corals and algae of the aerial ocean.

The boundary line crosses, at a distance of nearly seventeen miles of desert, a comparatively narrow and low sierra chiefly constituted by porphyritic and amygdaloid rocks. The point of crossing is marked by a natural monument, a fork formed by two bold vertically rising horns of solid rock. The sierra itself is a northerly continuation of a cordillera with the name Lóbota. The word seems to belong to the language of the Papago Indians, who have several large settlements in this vicinity; the meaning of the word, however, did not become known to us. About three quarters of a mile south from the line, a *cañon* intersects the Sierra de los Linderos, through which the western side is reached without much difficulty. In this natural opening a great deal of crystalline, primary, and transition rock is developed, though the igneous masses maintain at the same time their supremacy. The name, "de los Linderos," was given to this sierra on account of those two cliffs forming a fork, through which the line passes, and bringing, one to the American, the other to the Mexican side. Lindero, in Spanish, means a boundary or a landmark, and therefore the application of this name here.

Another desert plain, from seventeen to eighteen miles wide, separates the Sierra de los Linderos from that of de la Nariz. Though both of these mountain ranges appear, petrographically, very near related, there exists one striking difference between them. The former at least, at our point of crossing, is a real volcanic dyke at its base, in some places bordered by upheaved crystalline strata. Its crest of igneous masses, forced through a body of fantastically contorted, partly shattered walls and dykes of volcanic rocks, resembles a group of Titans, turned into stone whilst they were in the very act of assailing the heavens. On the other hand, the Sierra de la Nariz, consisting, also, of nothing but igneous masses, (trappitic and porphyritic,) appears more to be the result of simple, less intense, uni-lateral upheaving. Its crest, comparatively even, is nothing but the turned up edge of a vast bed of volcanic or volcanized rock, dipping in a north-easterly direction,

whilst its strike at an absolute height of from 200 to 400 feet is turned west.

The surface of its easterly slope is covered by a thick layer of loose boulders, of a black vesicular trap. On the strike stratification is visible even from some distance, the layers being of various thicknesses, from five feet and less up to twenty and twenty-five feet. The Sierra de la Nariz ranges in a slightly curved line, from south-east towards north-west, where, at a distance of about eight miles, it is connected with the Sierra del Ajo, of which it appears to be but a south-eastern ray. Next to the point of connection between the two sierras, that of the de la Nariz is divided into two subparallel running branches of which the westernmost is only short, not exceeding ten miles in length, whilst the eastern range continues for twenty miles. Near the intersection of the boundary line, a little to the north, quite a depression occurs, where the sierra hardly reaches fifty feet in height. In this vicinity it is also traversed by two open passes, the bottom of which is almost upon a level with the diluvial main. The vernacular name of this sierra is Spanish, and means "nose;" the reason of its application was left unknown to us.

To the north of the Sierra de la Nariz another one is visible, at a distance of about fifteen miles, which is the width of the intermediate level valley. It seems to be perfectly analogous in its petrographic character to the one of de la Nariz, having dip, strike, and stratification the same with the latter. Both these sierras are accompanied by a number of little trap-mounds, reaching out at the base of the former, from the level of the valley, not rising, however, higher than from thirty to forty feet. Springs are not to be found in any of these mountain ranges. The few animals of the wilds, also the Indians and travellers, depend here entirely on *charcos*. As we at the time were fortunate enough to encounter such water places, in the neighborhood of this sierra, where we least expected them, the name "Laguna de la Esperanza" (lagoon of hope), was given to it. This range seems to be, also, an eastern link of the Sierra del Ajo.

From the heights of the Sierra de la Nariz to the north-west, a bold and high range stands in sight. It appears more like a node or a compound of sierras, a forced consolidation of various branches. This mountain group bears the Spanish name, del Ajo, which means "a garlic." The reason for this singular name is based, as we were informed, upon

the morphological features of the sierra. Though probably constituted of similar volcanic rocks like the others, its structure is different. As it is seen from south-west, from the Liénagas of Sonoyta, a huge centre block, of either metamorphic, or more probably, volcanic or volcanized stratified rocks, is observed on the strike side to be in its middle penetrated from below by rocks, which, as it seems, are lithologically alike, but of columnar structure. The whole body is hereby divided into two nearly equal portions. The aspect of this, and the before-mentioned sierras, is indeed very singular, and impressed upon us the idea of geological mummies, on which metamorphism chemically and mechanically produced such thorough changes, altering their lithological characters, but preserving their morphological features. On the sides and at the base of this sierra, quite a number of volcanic peaks are towering up, one superviewing the other, but undoubtedly, all together, standing upon one and the same volcanic focus, however detached their situation above ground may appear. Thus the main body of the Sierra del Ajo resembles in its shape the bulbous head of a garlic. A comparison like this, though rather keen and parabolic, may be otherwise justified, as it implies, at the same time, the endogenous growth of both the sierra and the garlic head.

The mountain range of del Ajo also forms a sort of a dividing ridge between the waters of Sonoyta, running in a westerly direction towards the Gulf of California, and those waters turning in an easterly direction from the slopes of the Sierras de la Nariz, and afterwards taking, also, a south-westerly course.

On the westerly foot of the Sierra del Ajo, a wide valley is spread out, which, being hemmed in all round by mountain ranges, and having but one obstructed outlet, is what the Spanish call a "*ciénaga.*" Its southern border is formed by the Sierra Guehibabi, which is a Papago name of no known meaning. As the sierras just before spoken of strike the eye by their dark-brown, almost black color, the sierras to the south and west are constituted of metamorphic crystalline rocks with prevailing felspar. The color of these mountains, especially under the rays of a Sonorian sun, is a glaring white. Thus we find the often repeated, and somewhat fabulous sounding stories of general travellers well founded, when they talk, for instance, about the pass between a white and a black mountain, or something of that kind. On the foot of the eastern end of the Sierra Guehibabi, near the old mission of

Sonoyta, chloritic slates and greenstone come to sight. They appear, however, to be but local, and a branch of the same sierra ranging due north shows throughout that same white or light-colored felspathic crystalline rock. This branch being lowest in elevation and but short, until it is absorbed by the western outrunners of the Sierra del Ajo, was named Sierrita di Sonoyta. The eastern part of the *ciénaga* is open for travellers to Presidio di Altar. There the dividing ridge is nothing but a slight swell of the diluvial plain.

Besides the abundance of deep *charcos* and lagoons through its lower portion, this *ciénaga* is blessed with the origin of a small river, fed at its very outset by a large number of little springs, undoubtedly rising from a very great depth. Their water is beautiful, clear, of a bluish hue, of somewhat high temperature, and slightly brackish. Notwithstanding the rich supply by which the little river of Sonoyta is nourished at its birth, it is not able to remain a running stream. Before reaching a mile it disappears under ground, and regains daylight several times. The water, however, is constant enough to justify a settlement in its vicinity. The Roman church had once established one of her missions (Pimeria Alta) in this remote and desolate quarter of Sonora. This well intended establishment, however, like the little river of Sonoyta, did not show much vitality. Some poor fragments of miserable walls are the whole that is left, by which to recognize the spot near the outlet of the valley. This is occupied now by a group of a few Mexican and Indian huts, the inhabitants of which irrigate some tillable ground. The proportion of the latter is very small, and scarcely enough to satisfy fifty Papaga families.

In the physiography of the country the Sierra del Ajo, forming the north-eastern corner of the Ciénaga di Sonoyta, seems to be a remarkable monument, which establishes the real boundary between the coast and the interior. It is also in the north-western portion of the same that rich argentiferous and auriferous copper ores abound, containing, as it is said, sufficient gold and silver to defray the expenses of mining and separating the copper. These ores were rediscovered some years ago, and are worked now by a Californian mining association, called the "Arizona Company." This company, besides exploring first the stretch hence direct to the Gila River, opened also with considerable expense and labor a road through the mountain passes,

and provided, by means of artificial tanks, for the preservation of rain-water, which annually falls upon those regions.

Following the bed of the river of Sonoyta, a narrow pass leads without any difficulty into another *ciénaga*, which, being not so well watered as the one of Sonoyta, bears again the common desert character. Its diametrical extension is about like the former, and may be stated to have a width of fifteen miles each way. The Sonoyta stream winds its course through it, but forms only in the upper half, in two or three places, small shallow ponds, where, during the dry season, water may be got by digging.

Mountain and hill ranges, formed by the same felspathic crystalline rocks, border this *ciénaga* all round. The more open west end is limited by a swell of the diluvial beds, leaving but one opening for the occasional surplus of water from the Sonoyta River. This *ciénaga*, which may be called "Quitobaquita," partakes still more of the physiography of the California desert.

Quitobaquita signifies, in the Papago language, a small mountain gap or pass, which in reality is formed here by low mountain ridges, spurs of the Sierra del Ajo, Di Quitobaquita, and Guehibabi. Upon the rising ground on the west end of this *ciénaga* a wealthy Mexican established a cattle rancho. The inhabitants of the latter depend on spring water, which flows in abundance from some twelve to fifteen small springs, all rising in one line upon a bank which apparently has been formed by the same material they themselves had precipitated. The substance itself seems to be some form of carbonate of lime. The water of these springs resembles fully, in appearance and mode of issue, that of Sonoyta, and we shall not be mistaken in placing the phenomenon of both upon one physical base, and considering them to be mineral or thermal springs.

Leaving Quitobaquita the line passes over a broad ridge, dipping east and west, and forming a kind of yoke (jugum) between the Sierra of Quitobaquita and a mountain group to the south called "Los Cerros de la Salada." Here all round crystalline felspathic rocks prevail. The structure of these *cerros* indicates a general geognostical disturbance, under which these hills and mounds have been grouped together. They are of different absolute height, and their rocky parts are very much interspersed or covered with debris. In general the

entire arrangement and ranging of the sierras between this place and Sonoyta exhibits some deviation from the established rule of parallelism among all the sierras of north-western Sonora. The mountain ranges of Quitobaquita, Del Ajo, and Guehibabi appear like three gigantic rows of waves, which, after overreaching one another in discharging their contents, form a net of irregularly ranging mountain marshes.

The water of the little river of Sonoyta leaves its course above ground for the last time at Quitobaquita to follow its terrestrial course. Two miles below, on the south-east side of the Cerros de la Salada, fresh drinking water can be got by digging from two to three feet deep in the bed of the river. One mile further below, the water of the same stream is so exceedingly saline that not even starving mules will touch it. This salt water occasioned the name de la Salada, which is also applied to the mountain group placed next to it. Hence the country opens entirely in a southerly direction towards the coast, leaving free sight to a pretty bold but entirely isolated sierra of considerable height, which is named "Pinecate." This singular name, signifying a beetle, must probably have originated from some particular occurrence, for we have not been able to find out any reference the name could have to any peculiarity of these mountains. This sierra, about twenty-five miles distant from the line, is, for want of water, almost entirely inaccessible. It is renowned, however, through all Sonora, for its wonderful and inexhaustible layers of rock salt. It is stated that this precious material is stored up there in immense masses, and arranged under a diversity of strata varying in all tints and colors. The group of the Cerros de la Salada is most probably connected with the salt region of Pinecate.

After passing the Salada mountains a wide waterless desert stretches out, studded with a number of isolated little peaks and mounds of every size and shape, partly formed by our well-known felspathic rocks, and partly by igneous masses either trappitic, amygdaloid, or porphyritic. Southward this desert is bounded by low ridges and gradual risings of the diluvial main, and to the north and west by bold sierras alternately constituted of the before-mentioned volcanic and plutonic rocks. Westwards, at a distance of about thirty-five miles, a very rugged cordillera called Sierra del Tule limits this desert, but only to connect it by an intermediate narrow strip of desert with the great Colorado waste. Few insects and reptiles, fewer birds, and still fewer quadrupeds scan-

tily animate these forsaken regions, which death seems to hold under his seal. No reliable water-places invite the traveller on these plains to a short stop so as to recreate himself and his worn-out animals. "Either fly or die!" stands before his mind, and even animals have the same warning, and so both man and animal exert their last strength to escape. A number of graves and skeletons and numberless dried up carcasses along this road can witness how many lives have failed in reaching the other side.

The western portion of the desert, between the Salada peaks and the Sierra del Tule, rises towards the latter. This rise, together with an immense bed of black vesicular trap, commences in the playas of those *charcos*, in the centre of the plains, where, a short time after a rain, water may be found. Hence little black mounds and small white peaks increase in number, acquiring, gradually, a more elongated shape, and turning finally into low and abrupt sierritas. On drawing nearer towards the Sierra del Tule, the sierritas increase in size and number, and form parallel outworks of the Sierra Tule itself.

The huge crest-masses of this range appear like the white and black heads of long ocean waves, suddenly arrested and crystallized when in the midst of a chaotic uproar, thus telling their mythic tales of past eras. The upheaving forces employed in the formation of this sierra, or rather cordillera, left one uniform but nevertheless very eloquent mark on the face of these mountains. The combination of rocks is also very simple, consisting only of those black and white masses, in one place pressed closely together, and in another towering up, each one taking a separate shoot. Dip, strike, cleavage, and lamination are here obscure and contorted or overthrown, and in another spot distinct enough to be traced from two to three miles distance. Thus we are able to mark one mountain block formed by the upheaved corner or edge of one solid bed of felspathic sienite, or granite, changed into granitic or sienitic lava, or into regular trachyte, containing quite an amount of large crystals of glassy felspar. A singular aspect, too, is presented here, by mountains of such crystalline rocks, which had protruded an old bed of vesicular trap, and stand now like giants, wrapped up in the torn garments of dwarfs, now hanging in rags round their body. The morphological features of these gigantic stonewalls have much resemblance to the ice formations of the arctic oceans. Similar causes effected similar results in the formation and crystallization on

one hand of pluto-volcanic rocks, and on the other of consolidated aqueous masses. They both appear, in outline, perfectly alike, and so we observe here icefields, hummocks, packs, icebergs, and there, analogous in shape, beds of trappitic lava, contorted peaks and pinnacles of porphyritic and amygdaloid rocks, or the turned up edges of gigantic beds of metamorphic rocks, or the bell-shaped domes of trachyte, all together forced upon each other, broken, crushed, shattered, and formed over again. Both the icy and the rocky bodies float, each one half submerged, upon an ocean, the one upon the salt waters, the other upon the residue of a diluvial sea. The moving medium of both is also somewhat the same, and adequate to the masses to be worked upon. There are the oscillatory motions of the sea with one, and the vibrations of the earth's crust with the other.

Much like the Sierra del Tule is the one de las Tinajas Altas, deserving, also, like the former, rather the name cordillera. The petrographic features are almost the same, and there cannot be much doubt but that both are placed upon one base. The intermediate flats separating them are of the same repeatedly mentioned desert character. The same deadlike silence, and the same dreary desolation pervade this desert-chamber placed between the two sierras.

The mountain range of de las Tinajas Altas is the last one traversing North-western Sonora towards the Colorado del Oeste. From its crest but a few little peaks, reefs, and rocks are visible, forming the eastern coast of the Colorado desert, which, after this, becomes perfectly open. These orographical studs are in all probability but the crests and peaks of a submerged sierra, deeply overlaid by that same drift, which extends from here to the foot of the Californian Cordilleras, a distance of 130 to 140 miles. The direct distance from the Sierra de las Pinajas Altas to the nearest point of the Colorado may be set at forty-five miles.

One sheet of desert then stretches down to the banks of this river, unbroken, and only traversed in its middle by a light swell of the same forsaken sand. We incline to consider this rising in the midst of the desert, as the half-grown bud of an underground sierra, waiting only for nature's command to rise over the surface.

After a closer examination of the geological relief of North-western Sonora, we arrive at the conclusion, that such a state of country cannot be considered as having reached its physiographical point of cul-

mination, because its far larger portion lies buried under a thick veil, not only concealed from man's eye, but also inaccessible to those more beneficent agencies of creation, which alone could develope organic life upon the surface of this vast area, at present condemned to but a terrestrial existence.

Looking back over the mountains just now passed, we see them almost invariably dipping east and north-east, and their strike facing west or south-west. So we consider each range, sierra or cordillera, as the edge of a leaf in the great book of geogony. Few of them have been opened so as to allow some reading on one or the other page, whilst the greater number still remained closed, just with their edge turned up a little. It is our impression, that whenever time for further revelation shall arrive, these mysterious sheets will be turned from the west to east.

The sierras Madre, Santa Cruz, Pajarito, Santa Barbara, Santa Rita, and others of that region, have developed some parts of their geological history, whilst those western ranges have hardly commenced to do so. Earthquakes are not uncommon through the basin of the California Gulf; a mud volcano, on the eastern foot of the cordilleras of Lower California is still in activity; the lower Colorado, itself, is almost dry, and active to change not only its banks, but also its innumerable bends, of which, below the mouth of the Gila, exists only one retaining its original shape among all these changes. The navigators of this river call it, therefore, "the permanent bend."

In the face of these facts we cannot doubt that this country has not yet passed through all the phases of its existence.

We do not, however, believe that any great and violent general catastrophe will be necessary to bring the things to pass. A long continued, perhaps imperceptible rise of country, the simple increase of elevation, and especially the enlargement of the angle of inclination to which the level of these deserts may become subjected, might aid the torrents of the mountains and the sweeping winds to clear the surface of this land from its terrible burden, which is adverse to the purposes of man, and to the still higher ends of nature.

4. On the Carboniferous Limestones of the Mississippi Valley. By Professor James Hall, of Albany, N. Y.

Abstract.

The object of this communication was to show that certain reliable and well-marked subdivisions exist in the carboniferous limestone, as it is usually termed, of the Mississippi Valley. The subdivisions heretofore proposed, were in part founded upon certain supposed characteristic fossils, such as the Archimedes,* the Pentremites, etc., which, though reliable as individual species in their geological range, are not as genera characteristic of the subdivisions.

The subdivisions proposed in the report of Dr. D. D. Owen were, first, an upper and a lower series, each of which was again subdivided into several distinct beds or groups. For the sake of comparison, rather than for criticism, this table of formations of Dr. Owen is here given.

Professor Owen's Table.

Bituminous shale	
Bed of coal six to eight inches thick	
Upper concretionary limestone	20 ft.
Gritstones	10 "
Lower concretionary limestone	30 "
Gritstones	10 "
Magnesian limestone	10 "
Geodiferous beds	30 "
Archimedes limestones	50 "
Shell beds	15 "
Keokuk cherty limestones	15 "
Reddish brown Encrinital group of Hannibal	70 "
Encrinital group of Burlington	55 "
Argillo-calcareous group, Evans' Falls	75 "

The above represents an approximate thickness, as given by Professor Owen.

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* See description of *Fenestella* (*Archimedes*) in a following paper.

Professor Swallow, in his report on the Geological Survey of Missouri, subdivides the Carboniferous limestones, and the rocks below the coal-measures, as follows: —

Carboniferous limestones.	E.	Lower coal-measures	140 ft.
	F.	Ferruginous sandstone	195 "
	G.	St. Louis limestone	250 "
	H.	Archimedes limestone	200 "
	I.	Encrinital limestone	500 "
Chemung group.	J.	Chouteau limestone	70 ft.
	K.	Vermicular sandstone and shales	75 "
	L.	Lithographic limestones	60 "

Under each one of these divisions are given numerous localities, where the rock is well developed.

In descending the Mississippi River, we come upon the lowest and most northerly outcrop of the limestones, at Burlington in Iowa.

At this locality we have the following section in the descending order: —

1. Encrinital limestone.
2. Oolitic limestone, fossiliferous.
3. Compact arenaceous limestone.
4. Fine grained argillaceous sandstone or gritstone with casts of Spirifer, Chonetes, Productus, Bellerophon, Orthoceras, etc.
5. Green shale.

The entire thickness of 2, 3, 4, and 5, is about sixty-five to seventy feet; the base of the green shale, however, has not been observed.

These members constitute the Argillo-calcareous group of Evans's Falls in Dr. Owen's section; and the members J. K. and L. of Professor Swallow's section. The higher beds of these strata belong to the Chemung group, containing the same fossils as the rocks of that group in New York and elsewhere, and have been carefully traced throughout the intermediate space. It is quite probable that in strict parallelism the green shale of Burlington and Evans's Falls, which weathers to an "ash-colored earthy marlite," should be referred to the Portage group, since here it lies between well-marked Hamilton beds and the Chemung. And it is likewise probable that the lithographic limestone of Professor Swallow will be found more closely allied with the Hamilton than with the Chemung group.

We have, however, in the light-colored friable sandstones of the

Chemung group, a well marked and reliable horizon. The Oolitic bed is more closely allied by its fossils with the Chemung below, than with the Encrinital limestones above; though between the latter there is often no well-marked physical line;—so gradual and imperceptible is the change from what is termed Devonian to the acknowledged Carboniferous rocks.

The Encrinital limestone of Burlington, or, as we shall hereafter term it, the *Burlington limestone*, is characterized by its great number of Crinoids, of which Drs. D. D. Owen and B. F. Shumard have described numerous species. The rock is in a great measure composed of the broken and comminuted remains of this family of fossils. Large masses of the rock consist almost entirely of the separated but unbroken joints of the columns of various species of Crinoids.

This rock includes the "Encrinital group of Burlington," and the "Reddish brown Encrinital group of Hannibal," in Missouri, of Dr. Owen's section; the latter being in no respect different from the former, and holds precisely the same position in the series, having the same beds above and below it.

The "Encrinital limestone" of the Missouri report is likewise identical with the Burlington limestone, and is so recognized by Professor Swallow.

The Burlington limestone is succeeded by Cherty layers, with intercalated beds of light gray limestone; these are the Keokuk Cherty limestones of Dr. Owen. They have a thickness, altogether, of sixty to one hundred feet, and constitute the beds of passage to the next division of the limestones. These cherty beds form the rapids above Keokuk, so well known in the navigation of the Mississippi River. These constitute, also, the so-called Silicious formation of Tennessee and Alabama.

The second important limestone is recognized, both in the section of Professor Swallow and Dr. D. D. Owen, as the "Archimedes limestone," from containing the Archimedes of Lesueur, a Bryozoum of the Fenestella family, with a spiral axis.

On descending the Mississippi River this limestone is found at Dallas, at Appanoose, and opposite to Madison, and at Nauvoo, Illinois, and is largely developed at Keokuk; the "shell beds" of Dr. Owen forming a subordinate member of the mass. The fossil Archimedes is extremely rare in all these localities, as well as at Quincy, Illinois,

where the lower part of the rock is seen resting on the cherty beds which separate it from the Burlington limestone.

This limestone, which may for convenience be termed the Lower Archimedes limestone, or Keokuk limestone, contains numerous characteristic fossils. In the upper part we find *Archimedes*, rarely, *Cyathophylli*, *Spirifer striatus*, fish teeth, etc. Among crinoids are *Platycrinus Saffordii*, *Actinocrinus Humboldtii*, *Agaricocrinus tuberosus*.

The Keokuck limestone is limited above by a mass of shales, or marls with impure limestones, known locally as the "Geode bed," from the numerous geodes lined with quartz, crystals, chalcedony, calc spar, etc., which it contains;—and which have been distributed very widely throughout the United States. This mass constitutes the "Geodiferous beds" of Dr. Owen's section; but has not been recognized in the Missouri section.

Succeeding the Geode bed, and occurring in the same localities near Warsaw, Illinois, at Appanoose, and other places, is a bed of Magnesian limestone, recognized in Dr. Owen's section under the same name.

To the Magnesian limestone, which has a thickness of some ten feet, and is doubtless only of local development, succeeds a series of beds of blue "marlites," with intercalations of impure limestones, or, in some places, impure limestones separated by seams of blue marl. The upper portions become arenaceous, and sometimes contain small pebbles, forming the "Gritstone" of Dr. Owen's section. The central and principal portion is highly fossiliferous, abounding in reticulated bryozoa; and among these the axis of a species of Archimedes occurs in great numbers and of extraordinary size and perfection. So abundant is it that a score of individuals may sometimes be seen in the space of a few feet. This species is quite different from the one in the Keokuk beds; being more robust and the volutions of the spiral lip rapidly ascending. This limestone, in some localities, contains Pentremites in considerable numbers.

This *second* Archimedes limestone seems not to have been recognized in the section of Dr. Owen; and judging from localities cited, it appears to have been confounded with the lower Archimedes, or Keokuk limestone. The position, however, of the Warsaw Archimedes limestone is above the Geode bed; the Archimedes is a distinct species, and it is associated with several species of crinoids, fish teeth, etc., which do not occur in the lower beds.

The arenaceous bed which terminates this group, and which like-

wise contains Archimedes and joints of crinoidal columns, is succeeded by a light gray compact limestone, which is often concretionary or brecciated in its structure. Its most conspicuous fossil, in many localities, is *Lithostrotion floriforme.*

This limestone is termed by Dr. Owen the "Concretionary limestone," and by Professor Swallow the "St. Louis limestone."* It is the same rock which forms the low cliff below Keokuk, near the mouth of the Desmoines River, and at St. Francisville, Missouri; the greater part of the bluffs on the river for some distance above Alton, Illinois; the limestone of St. Louis, in whole or in part; the limestone of St. Genevieve; the limestone of Prairie du Rocher, Illinois; and in part of the bluffs bordering the American bottom below Alton.

At this point the sections of both Dr. Owen and Professor Swallow cease, so far as limestones are designated. The concretionary limestone of Dr. Owen is succeeded by sandstones and shales of the coal-measures; which is the true order at the mouth of the Desmoines and other places, but not universally true. In the section of Professor Swallow, the St. Louis limestone (concretionary limestone of Owen) is shown to be succeeded by a brown or ferruginous sandstone, F. of section in Missouri report; and upon this rests the lower coal-measures.

This order is likewise true in some parts of Missouri and of Illinois; but it is not everywhere true in these States. The ferruginous sandstone is in turn succeeded by an extensive and important limestone formation, which consists of beds of limestone of greater or less thickness, alternating with thin seams of marl or shale, and in some parts heavy bedded limestone of considerable thickness without shaly partings, or with very thin ones. The group embraces, likewise, one or more heavy sandstone beds, and a mass of green shale or marl, more than fifty feet thick in some localities.

This formation constitutes the limestones of Kaskaskia and Chester, Illinois; and those below St. Genevieve in Missouri. They likewise occur at other places on the river, and form the greater part of the limestones of Southern Illinois, and Indiana, and those of Kentucky

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* After a careful examination of the locality cited by Dr. Owen, I am unable to find a "*second* concretionary limestone;" though it is not difficult to see how such an error may have occurred in measuring the section near the mouth of the Desmoines River.

This limestone is likewise known as the Archimedes limestone, and sometimes as the Pentremital limestone from the abundance of Pentremites it contains. The species are distinct from those of the Pentremites of the Warsaw Archimedes limestone. This rock has evidently been always confounded with the lower Archimedes or Keokuk limestone, as is shown by localities cited in the reports above-mentioned, and in other publications upon Western geology.

The species of Archimedes, which it contains in great numbers, are quite distinct from the other two named; and the character of the axis of these fossils alone, is quite sufficient to distinguish the rock from either of the lower ones. The stratigraphical position of this rock is most clearly defined and readily determinable. The assemblage of fossils is quite distinct from all those in the rocks below, and there remains no reason for confounding it with either of the other divisions.

In following down the course of the Mississippi River, the St. Louis limestone is seen to pass beneath the ferruginous sandstone F.; and upon the latter rests the limestone group of Kaskaskia in Illinois, and of St. Mary's in Missouri.

From these data we are prepared to show the true order of the successive members of the carboniferous limestones of the Mississippi valley in the States of Iowa, Illinois, and Missouri, and also in Indiana, Kentucky, Tennessee, and Alabama.

The following section illustrates the preceding statements regarding the order of superposition among the different members of the limestone series.

VII.	Coal-measures.	
VI.	Kaskaskia limestone, or Upper Archimedes limestone.	Kaskaskia and Chester, Ill.; St. Marys, Mo.
V.	Gray, brown, or Ferruginous sandstone overlying the limestones of Alton and St. Louis.	Below St. Genevieve, Mo.; between Prairie du Rocher and Kaskaskia, Ill.
IV.	"St. Louis limestone." Concretionary limestone" of Dr. D. D. Owen.	Highest beds below Keokuk, Alton, St. Louis, St. Genevieve.
III.	"Arenaceous bed." Warsaw or Second Archimedes limestone. "Magnesian limestone."	Warsaw and above Alton, Ill.; Bloomington, Spergen Hill, etc., Iowa.
Beds of Passage.	Soft, shaley, or marly beds with geodes of quartz chalcedony.	

II.	Keokuk, or lower Archimedes limestone.	Keokuk, Quincy, etc.
Beds of Passage.	"Cherty beds," sixty to one hundred feet.	Rapids above Keokuk.
I.	Burlington limestone.	Burlington, Iowa; Quincy, Ill.; Hannibal, etc., Mo.
	Oolitic limestone and Argillaceous sandstone of the Chemung group of New York.	Burlington, Iowa; Hannibal, Mo.; and other localities.

The difficulties which have occurred in the way of a reconciliation of the views of western geologists, have arisen in part from the fact that these different limestones have not an equal geographical distribution; there being no point on the Mississippi, within our knowledge, where a section at right angles to this valley will embrace all the beds here enumerated. The limestones, likewise, change their character when examined in a north and south direction, owing to causes which will be enumerated. The fossil forms which have mainly been relied on for characterizing the divisions, have been, to considerable extent, only of generic value, and specific differences have not always been properly recognized.

In the geographical distribution and the changes of lithological character, at different points, we have yet much to learn. These successive formations of limestone have been deposited in an ocean which was gradually contracting its limits upon the north. The lowest, or Burlington limestone, has, therefore, a greater extension northward than either of the succeeding groups, and its gradually thinning edges stretch far towards Iowa City; near which latitude was the northern boundary of the ocean, or at least the limit of its animal life. Considerably to the southward of this line we first find the attenuated northern edges of the Keokuk limestone, mingled with much earthy sediment, and often consisting of a few thin beds of encrinital limestone intercalated among other beds of an argillaceous character. It is only further south, in the neighborhood of Nauvoo and Keokuk, that this limestone first exhibits decidedly its characteristic features. The limits of the ocean which admitted of rock deposition at this period, never extended so far north, by many miles, as in the period of the Burlington limestones.

The Warsaw Archimedes limestone appears to have been nearly

co-extensive with that below, so far as known at present. The St. Louis limestone extends northward, also, nearly or quite to the same distance, but only in a thin, brecciated, or conglomeratic mass; and it is only on descending the valley to the vicinity of Alton, that this rock appears in any considerable force.

To these beds succeed the sedimentary deposit of Ferruginous sandstone, which, in the river valley, is not known far to the north of St. Louis; while the succeeding Kaskaskia limestone becomes important in the neighborhood of the Kaskaskia River; and is known in the interior as far north as Prairie de Long, increasing in force as we go southward.

We have most clearly, therefore, the evidence, that the limits of the ocean, admitting of calcareous deposition, was gradually contracting, at least in the direction from north to south, leaving the more southerly portions as the areas of greatest development for these limestones, which, in the successive periods, were gradually extended farther and farther to the southward.

Some interesting inquiries are suggested by these facts; and at the same time they afford, in some degree, the solution of a difficulty which has heretofore been unexplained.

It is well known that no limestone of the age of those here described, occurs beneath the coal-measures on the western side of the Appalachian coal-field, north of the Ohio River, nor upon the eastern side of the same field, until we reach the central portion of Virginia. The same is true of the coal-fields of Nova Scotia and New Brunswick, according to Professor Dawson; the northern sides exhibiting no underlying limestones; while these rocks do appear, coming out from beneath the coal-measures, on the south-eastern side. The same phenomena occur in regard to the northern portions of the Illinois and Iowa coal-fields.

At the same time, I have ascertained in the most satisfactory manner, that the coal-measures of Iowa, Missouri, and Illinois, rest unconformably upon the strata beneath. Whether these strata be the carboniferous limestones already referred to, the Devonian, the upper silurian, or lower Silurian rocks; in either case the measures are unconformable, differing only in degree.

It would appear that at a period long preceding the commencement of the carboniferous limestone deposit, the ancient ocean began to contract its area; that this contraction was due to the uplifting of the

older rocks upon the north; and that this state of things continued throughout all the period of the limestone deposites. That during this period, or at its close, and previous to the deposition of the coal-measures, the older strata becoming uplifted, and at some points broken by faults, in many places acquired a dip of from ten to thirty degrees; that denudation had worn down, to some extent, the inequalities caused by this uplifting of the strata, and produced other irregularities of the surface.

The coal-measures extend much farther to the north than the northern limits of the carboniferous limestones, and are spread out over the thinning and slightly inclined edges of these beds, and over the more disturbed and more highly elevated edges of the rocks of the preceding periods. Thus the coal-measures rest respectively upon all the formations, from *lower Silurian* to the *carboniferous limestones*. The only explanation we can offer is, that the area of the ocean, which had contracted up to the time of the coal period, was afterwards extended by the sinking of the land; allowing the sandstones and shales of the coal-measures, as well as subordinate beds of limestone, to be spread over much wider areas than the preceding formations of carboniferous limestone. This accounts for the absence of the carboniferous limestone, in the northern portions of all the coal-fields.

It is true, however, that the carboniferous limestones of Nova Scotia have a more northerly extension than the northern limits of the Appalachian coal-field; but if these limestones of Nova Scotia be of the same age as those of the south-west, their occurrence may be due to the direction of the ancient ocean margin, or the line of ancient coral reefs. It appears that this direction may have been from the south-west to the north-east, at least for that portion of the country east of the Cincinnati axis; while on the west of that line, the lower carboniferous limestones make a northerly bend, as if at that period the valley of the Mississippi admitted of a more northerly extension of the coral reefs.

This view, sustained by facts, while it offers a general solution of the difficulty respecting the non-occurrence of carboniferous limestones on the northern sides of all the coal-measures, at the same time suggests an explanation of the greater accumulation of conglomerates and coarser materials in the same position.

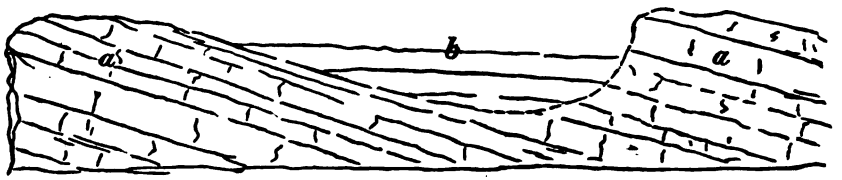
The high elevation of the older strata, and the inequalities of surface on which the western coal-measures rest, prove conclusively that ex-

tensive denudation had taken place previous to the coal period; and this fact, connected with others of similar character, should suggest a caution in our conclusions regarding the vast influence of modern denudation upon the surface of the globe.

Among the remarkable and interesting consequences of this ancient denudation, it is not unusual to find depressions among the inclined strata of the silurian rocks, filled with regular coal deposits, lying usually in a horizontal position, or with a slight dip, varying from that of the surrounding rock. These outcrops, which sometimes occur in ravines, have all the aspect of regular coal-measures, which, from the direction of the bed, would penetrate the bank, but which are, nevertheless, cut off by the inclined strata, within a few yards. Isolated masses of this kind are not uncommon, both in Iowa, Illinois, and Missouri, lying at the foot of elevations, and apparently penetrating the adjoining elevated ground. In the latter State, these, in many instances have been worked entirely out, and proved to have no connection whatever with the adjacent beds, or with any other coal in the vicinity.

In several localities on the Mississippi River, in Iowa, the older rocks, dipping to the northward at an angle of perhaps ten degrees, present the outcropping edges at points more or less distant from each other, while the intermediate space is occupied by strata of the coal-measures, lying in a horizontal position. These phenomena have been mistaken for faults; but they are far different in their origin, and the coal-measures have apparently never been disturbed from the time of their deposition.

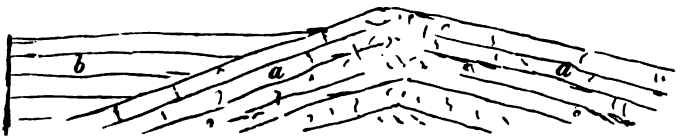
Among the examples of this kind may be noticed more than one between Davenport and Le Claire. Within three miles of the latter place, the strata of upper Silurian limestones are dipping to the northward, and between two points of outcrop, horizontal beds of coal shale, sandstones, and iron ore, occupy the spaces, thus:—



a a. Outcrops of Silurian limestone, as seen above the level of the river, dipping at an angle of 15°.

b. Coal, shales, and sandstones lying in horizontal position.

In another instance, the coal-measures present the following relation to the underlying rocks: —



a a. Axis of Silurian limestone.

b. Horizontal coal-measure strata, traced to within three feet of actual contact with the limestones, which dip at an angle of 30°.

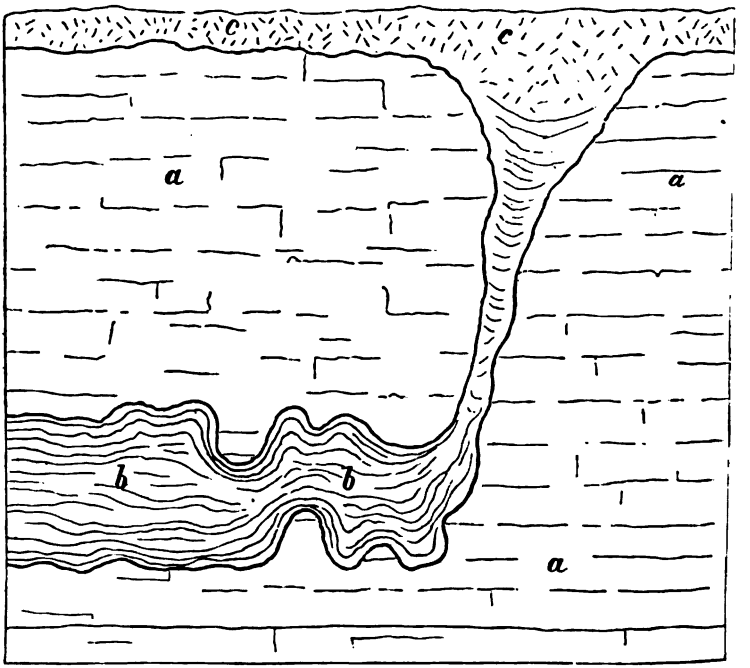
A still more interesting exhibition of phenomena attendant upon this condition of the strata is the occurrence, in limestones of the age of the Hamilton and Upper Helderberg groups, of rounded or irregular masses of clay, like the underclay of coal seams. These masses, which are seen in sections along the river, and in quarries, often present simply the appearance of a spheroidal mass of clay. Sometimes the larger mass is traced through a narrow seam to a connection with another similar one in a higher bed of the rock; and it not unfrequently happens that these clay seams, which are always vertical to the bedding of the limestone, may be traced to the surface, and the clay found mingled with the superincumbent materials as if having a common origin. On examining the surfaces of contact between the clay and limestone, we find the former adhering closely, and when separated, the limestone still retains a striated coating of the clay. The clay is laminated, and the laminations are curved or irregular, but never parallel to the lines of bedding in the limestone.

A single instance of this character satisfied me that these masses of clay were of subsequent deposition to the limestone; and that they filled cavities which had been made by denudation, like modern caverns in limestone.

This example was in the vertical face of a quarry, presenting an elevation of thirty or forty feet. From the loose soil above, was a depression at the surface of the limestone; this depression was the commencement of a broad, funnel-shaped opening, which gradually narrowed below, till within ten feet of the bottom, where it spread out on one side, having an irregular arched roof with numerous smaller archings, and an unequal floor. Its termination to the left had in part been cut off. This cavity from top to bottom was filled with hard clay, like the

underclay of coal seams. At the mouth of the funnel it was of a reddish brown hue, but soon became of the ordinary gray color below.* The laminations of this clay, in the upper part, conformed to the curvatures and inequalities of the roof of the ancient cavern, and exhibited every appearance of having flowed in while in a semi-fluid condition; while the hydrostatic pressure of the mass above, operating through the deep funnel, had forced the soft clay against the roof, causing it to assume, in its lamination, the same curvatures and irregularities.

In the midst of this mass of clay was the impression of a large *Euomphalus;* quite distinct from any fossil known in the surrounding rock, and very similar to a carboniferous form. The shell itself I did not see; and with this exception, I found no traces of fossils in the clay.



aaa. Limestone of Devonian age.
bbb. Ash-colored clay, similar to the underclay of a coal seam.
cc. Gravel and yellowish loam.

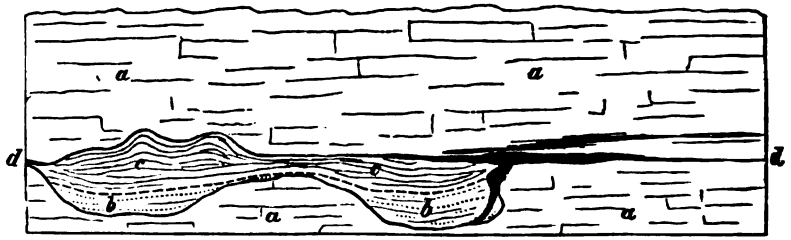
* The reddish brown color is simply due to infiltration from the ferruginous drift above.

It seems impossible, therefore, to resist the conclusion, that after the uplifting of these rocks, the denudation of the surface, and the wearing of caverns below, the materials of the coal-measures were distributed over the surface, filling these cavities, and depositing the successive members of the coal series upon the older rocks.

If any thing were wanting to complete the chain of evidence and carry the most conclusive proof, it is to be found in a section near Iowa City. In a cliff of limestone of the age of the Upper Helderberg of New York, where the strata are nearly horizontal, we have the following phenomena. Along the line of separation between two beds of limestone, appears a black band extending for thirty or forty feet; beneath this, occupying less horizontal extent, and partially filling a depression excavated in the limestone beds below, is a thicker layer of clay, precisely like that filling the cavities before described, and of the character of underclay; and still below this, occupying the depth of the cavity, is a coarse sandstone. This sandstone, in its lines of lamination or bedding, follows the curvatures of the limestone upon which it lies, gradually filling up the cavity from below, and extending its laminæ above as the space becomes wider. Upon this comes the underclay, filling the upper and broader part of the cavity, and having a greater horizontal extent than the sandstone below. Above this underclay, and stretching for several yards on either side, filling the open seam between the beds of limestone, is a band of black carbonaceous mud, the lower part slaty, and the upper part having the character of *cannel coal.* Here we have all the phenomena attending a coal-measure seam of coal; the sandstone, the underclay, and the seam of coal resting upon the latter: and as if nothing were wanting to complete the similarity, the slaty portion of the seam contains *fish teeth* of carboniferous character. All this is inclosed in limestones, which, in the State of New York, where the series is more complete, lie at a depth of more than 5,000 feet below the coal-measures.

In this instance the explanation is clear enough. It is only a little more complete in its members than the preceding example, while the aperture of admission from above is not visible. The coarse and fine sand were first transported; and falling through an opening in the rock, continued in deposition in this cavity, while a bed of similar sandstone was being formed outside, and upon the bed of the sea. This ceased, and then came the underclay, which was formed in like manner while

the underclay deposit of extensive coal beds was going on. Lastly appeared the carbonaceous mud, derived from a coal seam, or from the materials forming one of the seams of the coal-measures.



aaaa. Limestone of Devonian age.
bb. Coarse sandstone in curved laminæ.
cc. Ash-colored and greenish ash-colored underclay.
dd. Coal seam with shaly mud containing fish teeth.

There is here no mingling of materials, as if resulting from the breaking up of a coal seam at a later or modern period, and the filtration through a seam into the rock; on the contrary, every part is as distinct as in the coal-measures elsewhere, and it could only have resulted from a participation in the causes then operating to produce those extensive beds of sand, clay, shale, and coal, which make up the coal-measures.

It should not be forgotten, moreover, that this point is near the northern margin of the coal-fields, and beyond the limits of any productive coal seam; a few isolated patches of sandstone and shale being all the remaining evidences of the existence of the series in that vicinity.

This cavernous condition of the limestone is not confined to the immediate vicinity here described, but extends over large areas in Illinois and Iowa. The fissures are sometimes partially filled, and sometimes open.

In Wisconsin, Illinois, Iowa, and Missouri, the fissures or caves occupied by the lead ore are apparently of similar character and origin; the period of their production being a point for discussion. Whatever may be said to the contrary, it appears still very certain that these lead-bearing fissures have no connection with the rock below; and also, that the character of the fissures, with the material filling them, indicates an action from above. That these cavities were excavated, and

subsequently filled or partially filled with the ores of lead, zinc, or iron, by infiltration from above, as stated elsewhere by the writer,* seems as well settled a problem as that the coal seam just noticed is due to infiltration from above.

The age of the rock in which the lead occurs is not a question affecting the origin of the mineral matter; for while in Iowa, Wisconsin, and Illinois, the lead rock is an upper member of the Trenton limestone period, it is in Missouri the calciferous sandstone, a rock far older than the Trenton period. The mode of occurrence of the ore is similar in both places.

The fact that the calciferous sandstone in Missouri is the lead-bearing rock, and that sometimes in Upper Iowa and Wisconsin the same rock contains some lead ore, has induced the belief that the origin of the ore is from below. It is true that the calciferous sandstone is spread over large areas of country on the north of the productive lead region of Illinois, Iowa, and Wisconsin, but thus far it has yielded no valuable lodes. It is likewise less cavernous than the lead-bearing or Galena limestone, and far less so than the same rock in Missouri.

From what we know, it appears that neither the carboniferous limestones nor the coal-measures ever extended so far north as the northern lead-bearing rock, while these strata do occupy the country around the lead region of Missouri, and outliers of coal-measures often rest directly on the calciferous sandstone, the lead-bearing rock of that State.

There is, therefore, a strong evidence in favor of regarding these fissures and caverns, whether filled or otherwise, as having been formed during the Carboniferous period, and previous to the deposition of the coal.†

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* The same views in reference to the origin of the lead ores are entertained and have been published by Mr. J. D. Whitney.

† In making this statement the writer would not be understood to say that similar fissures and caverns may not have been produced in these rocks during the modern period, through the drift or other degrading agencies, which, at the same time, may have removed the clay or other mineral matter from caverns of previous date, rendering the determination of the period of their origin a matter of considerable difficulty. At the same time the existence of the fissures filled with mineral matter, accompanied or unaccompanied by a peculiar clay quite different from the drift materials of the region, or filled with this clay alone, or with indurated clay like the underclay of coal seams, either with or without the presence of sandstone and coal all point to a period long anterior to that of the modern drift.

The elevating forces which have raised the precarboniferous strata to their present inclination throughout the West, have had a determinate direction; and this direction has been from north-west to south-east, parallel to the great mountain ranges on the west, and nearly at a right angle with the Appalachian chain on the east. So far as my opportunities permitted the determination, the general direction is north 40° or more west.

In descending the Mississippi, we first notice that the strata rise and fall in broad undulations, which cross the direction of the valley from north-west to south-east. Still lower down we meet with more abrupt anticlinal axes; and in one of these, at the Upper Rapids and below, are several minor plications. Below Davenport there is considerable regularity; and between this point and Cap au Gris are again broad undulations, which reveal, successively, all the strata from the carboniferous limestone to the lower Silurian rocks. In approaching Cap au Gris from the north there is a gradual rising of the lower strata, so that the Trenton limestone is beautifully defined for some distance; and beneath it lies a magnesian limestone apparently of no great thickness. The dip to the north-east increases, and from beneath these limestones the sandstone rises in a bold escarpment continuing for three fourths of a mile, and presenting several hundred feet of thickness. This elevation suddenly declines to the southward; and we find the Burlington or lower carboniferous limestone standing vertically by the side of the lower sandstone. The limestone soon assumes a steep, and gradually a more gentle dip to the south, and the succeeding members come in successively. This fault, which is in fact an anticlinal axis, has a north-west and south-east direction, and, according to the observations of Mr. Worthen, extends far into Illinois.

Below St. Louis, in the vicinity of Selma, there is another decided anticlinal axis, bringing up the lower sandstone. According to the Missouri report, the lower limestones and sandstones are again brought up in the vicinity of Bailey's Landing, but I have personally examined the strata at this place only so far as to decide that the upper Silurian strata appear from beneath the upper Helderberg and Hamilton groups; beyond which the carboniferous limestones appear to come in unconformably in the synclinal axis.

Still another axis of very decided character brings up the Trenton limestone in great force at Cape Girardeau, on the Missouri side, and at

Orchard Creek, below Thebes, on the Illinois side of the river. This axis affects all the southern portion of Illinois, below a line drawn from Fountain Bluff, on the Mississippi, to near Golconda on the Ohio. In some parts of its course this axis would appear to have a direction of nearly north 35° west, and south 35° east. In a country, however, where denudation has taken place to such an extent, and succeeding strata are spread over the uplifted edges of those below, it is often difficult to determine the exact direction, until traced over a wide extent.

That these lower axes crossing the Mississippi are the results of the great movement which elevated the fundamental strata of the western mountain chain, we can have little doubt. The forces that there acted upon the huge pile of sedimentary strata, raising them into high mountain chains, here operated upon a thickness of a few hundred feet; and we may have, not only the dying out of the elevating force, but also the diminished thickness of the strata for the subject of its action. If the force which elevated the Rocky Mountain chain acted only on the palaeozoic strata, the greater amount of material in that direction would give greater elevation to the ridges, which under similar force would die out in the Mississippi valley for want of material to be elevated.

The discussion of this part of the subject, however, does not properly enter into the present paper, and will be postponed to another accasion.*

A few words may suffice to express for the present the general features of the series of these limestones on the south of the Ohio River. All the members, with the exception of the higher or Kaskaskia limestone, gradually thin out to the south. The "*Siliceous Group*," as it is termed in the Geological Report of Tennessee, lies at the base

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* See Introduction to Vol. III. Paleontology of New York. I may remark in this place that the observations made, and the collections brought home by Captain Stansbury, from the Salt Lake region, demonstrate that the upper carboniferous limestone, in an unaltered or scarcely changed condition, and bearing numerous fossils, rests unconformably upon metamorphic rocks of older date corresponding with what is so well shown in the Mississippi valley.

The topography accompanying these observations, also shows that these mountains of limestone have a nearly north and south direction; corresponding, doubtless, with the direction of the fundamental axes of the country.

of the carboniferous limestone in that State. This siliceous group is simply an extension of the cherty beds lying between the Burlington and Keokuk limestones, represented in the section between I. and II, which become largely developed in the south. The Burlington limestone is rarely seen, occupying a few feet of thickness beneath the "Siliceous Group." The Keokuk, Warsaw, and St. Louis limestones have thinned out so far as to form no important feature in the series, while the Kaskaskia limestone predominates over the whole country; and is there the great carboniferous limestone, yielding its abundance of Pentremites and Crinoids throughout its extent in Tennessee and Alabama.

NOTE. — So far as I know, the first notice of the unconformity of the Western coal-measures with the older rocks, was brought out, at the Providence meeting of the American Association for the Advancement of Science, in a discussion upon a section of the coal-measures of Northern Illinois, presented by Edward Daniels, Esq. This gentleman afterwards visited and reëxamined the locality, and communicated to me the following section as confirmatory of the views I had there expressed. The communication bears date of November, 1855.

a. Calciferous sandstone.
b. St. Peters sandstone.
c. Trenton and Galena limestone.
d. Coal-measures resting unconformably upon the rocks below.

In a Report upon the Mineral Resources of the Illinois Central Railroad, by J. W. Foster, published in 1856, a section similar to the one above is given; and the credit of the discovery of the relative position of the two series of rocks is there attributed to Dr. Norwood, the geologist of Illinois. It is certainly probable that Dr. Norwood has been aware of this fact for a long time, and the writer, in common with many of his friends, has had occasion to regret that Dr. Norwood has not long since published some portion of the accumulated facts of many years of investigation.

Although aware, for several years, of this relative position of the lower rocks and the coal-measures, yet I was never so fully impressed with the high interest and importance of the matter, until I had carefully followed out the successive members of the carboniferous limestone series. Disclaiming any desire to appropriate the discoveries of others, the writer has presented, in the preceding paper, the facts that came under his own observation, and the conclusions which seemed legitimately deducible therefrom.

I should do injustice to my own feelings were I not in this place to acknowledge the valuable aid rendered to me by Mr. A. H. Worthen, my assistant in the Geological Survey of Iowa, whose intimate acquaintance with the principal localities of the carboniferous limestones in the Mississippi valley, enabled me to accomplish my investigations in much less time and with far more satisfaction than I should otherwise have been able to do in a single season. We explored together these formations as far as the mouth of the Ohio, after which Mr. Worthen carried on, under my direction, the observations through Tennessee and Alabama, with a view to the recognition of the groups established in the investigations in Iowa, Illinois, and Missouri.

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5. Remarks on Niagara Falls. By Professor L. R. Gibbes, of Charleston, S. C. (In the form of a letter addressed to James Hall, President of the Association.)*

A pamphlet of Desor's † has lately fallen into my hands, in which he opposes your view of the condition of the Falls of Niagara, after a supposed recession of one and two miles, and, arguing from the rate of recession of the American Fall, since the time of Hennepin, expresses the opinion that the falls, instead of receding at the rate of a yard per annum, do not recede a foot per annum, and in fact that the rate is a *mere fraction of a foot.*

Now I cannot assent to his applying to the Canada Fall the result drawn from the American Fall, since he omits to take into consideration the very different rate of recession of the two falls. If we assume, what is generally granted, that the gorge or chasm, from the bluffs at Lewiston to the Canada Fall, has been excavated by the action of the falls themselves, then there must have been a period, anterior

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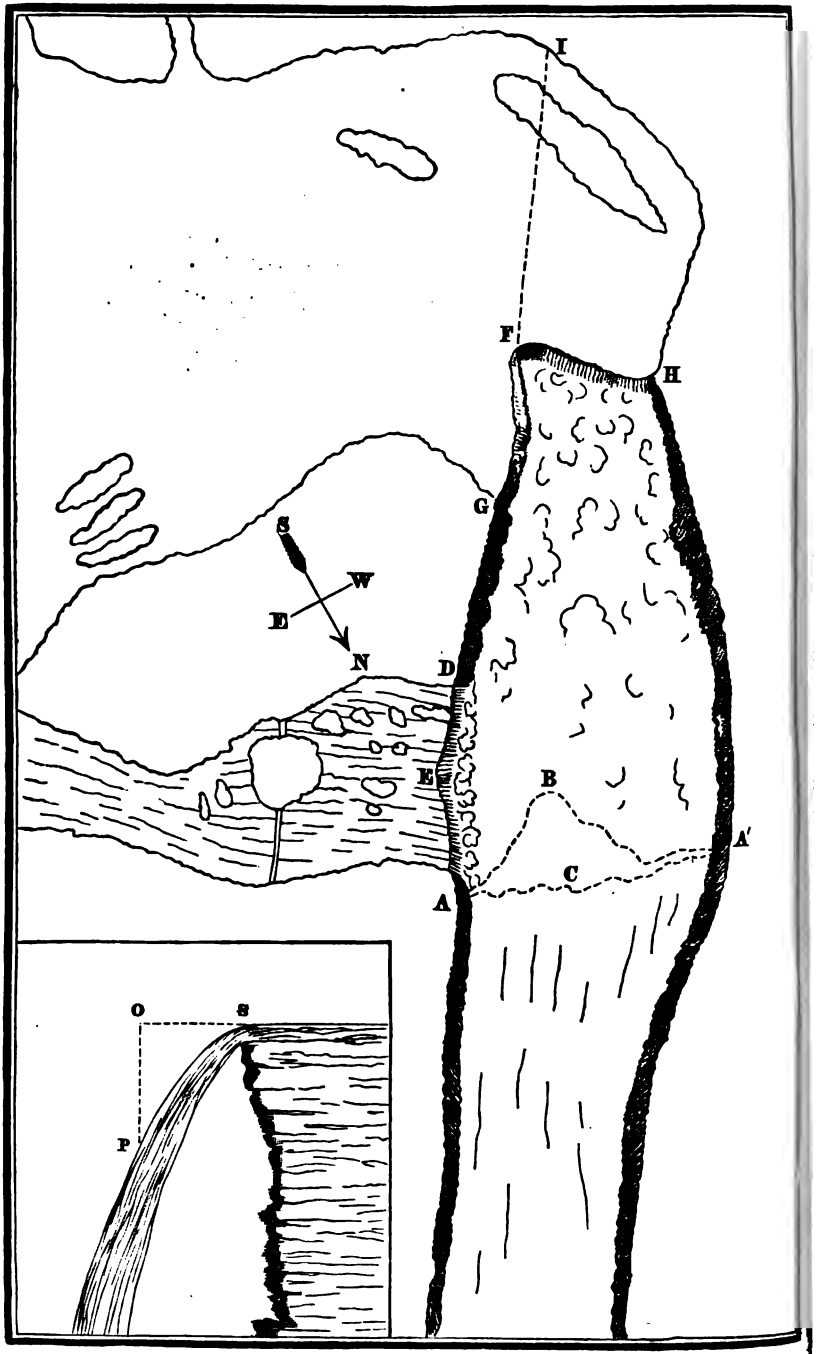
* This paper was communicated to the President of the Association, at the Albany meeting, with a request that he would lay it before the Association, with his comments. For want of time and ability on his part, it was not brought before the meeting, but was presented to the Standing Committee, who directed that it should appear in the proceedings. — J. H.

† Extracted from Bulletin de la Soc. des Sci. Naturelles de Neufchatel. Tome III.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to the division of the falls into two as at present, when there was but a single fall extending from A to A′, just below the American Fall, whose brink was along some irregularly curved line as A B A′ resembling that of the Canada Fall at present, or along some irregular line A C A′ approximating to the straight line joining A A′, resembling in this particular the American Fall. Then, if we assume that the river or portion of the main stream now forming the American Fall did at that time communicate with the main stream by the outlet A D, it will follow that while the centre of the American Fall receded from B or C to E, the centre of the Canada Fall receded *in the same interval* from B or C to F. From C to F is at least three times the distance from C to E, and from B to F is about four times the distance from B to E, so that *the recession of the Canada Fall is, on this supposition, at least from three to four times as rapid as that of the American Fall.*

This point is overlooked, or at least omitted, by Desor, so that his result drawn from the American cannot be applied without modification to the Canada Fall. I do not find that you have anywhere taken notice of this inequality of recession, or alluded to the causes which have produced it, nor can I find that other writers on the topography, geology, or phenomena of the falls, as Eaton, Hayes, or Rogers, make mention of it.

Putting aside the consideration of any actual inequality in time of action, that is, regarding it as impossible or exceedingly improbable that there should have been any natural dam or continuous obstacle from A to D, which gave way, some time after the main fall had passed the point D, permitting the American cascade then to begin its fall, there will remain two causes for the unequal recession of the two falls. These are difference in the volume of water, and unequal facility of abrasion possessed by the strata of rock in the two directions, C F and A′ A. Now, do either or both of these causes exist? if they exist, are they sufficient to account for the effect, the inequality of recession? It is twenty years since I visited the falls, but from my own recollections, as well as from the representations of visitors and the impression given by views of the falls, there can be no doubt that the volume of the Canadian Fall is much greater than that of the American Fall, and not only in length of the circuit of the brink, but in depth of water also, and possibly also in the velocity. With regard to unequal facility of abrasion in the two directions I know nothing but what the falls

themselves may show, for, as I have said, the geological observers do not appear to have mentioned it. That there is an unequal facility of abrasion in different directions appears to be indicated by the present condition of the falls. It is a very remarkable circumstance, and one whose value in the discussion of the past and future condition of the falls does not appear to be noticed or insisted upon, that the point A, the northern extremity of the American Fall, the point F, the vertex of the Canada Fall, and the two angles of Goat Island, D and G, are nearly in a right line, parallel to the general course of the gorge below, and at right angles to the general direction A A′ of the brink of the fall. It would appear, therefore, that the fall which had excavated the gorge below A A′, in a certain direction, had continued this excavation in the same direction, *uninfluenced by the presence and action of the American Fall*, except by the abstraction of that body of water, and had now assumed the position F H. With respect to its future condition, the Canadian Fall may be regarded as consisting of two portions, the one, F H, corresponding, in its relations to the strata beneath, to the original fall A A′, and the other, F G, in like relations, corresponding to the American Fall. If this view be correct, the general course of the Canadian Fall will be towards the point I, and the formation finally of a fall along the line G I, whose recession will be slower than formerly.

During the interval of time that the main fall was receding from A A′ to F H, a distance of about 1,000 yards, the American Fall must have receded from some line A D left by the abrading action of the main fall to its present position. The amount of this recession Desor estimates at forty yards, and this gives a rate of recession twenty-five times greater in one direction than in the other. This result must be reduced on account of the *gradual* development of the American Fall, while the main fall was receding from A to D. The result of this gradual development, will be the same as from the display of the whole force of the fall for half that time, and as A D is about one third of A F, if we suppose a nearly uniform rate of recession of the main fall, the reduction will be one sixth of the whole, leaving the ratio of recession as 1 to 20 or 21. This effect can scarcely be due to the difference of volume of water solely. The volume of water passing over any linear yard of the brink of either fall depends on the velocity and depth, and I have no means of ascertaining either of

these factors. It has been reported that the hull of a vessel, sixteen feet from deck to keel, was sent over the Canada Fall, that the deck was level with the water, and that the keel met with no obstruction in its passage; it was hence inferred that the depth of water at the brink of the fall was at least twenty feet. If we give the half of this depth to the American Fall, which I think is not too great, the above result would require a depth of 200 feet of water at the Canada Fall, greater than the whole height of that fall, 156 feet. I have been behind the Canadian Fall, and proceeded some distance along the ledge of rock, but can form no reliable estimate of the height of the under surface of the sheet of water. It can scarcely be less than fifty-six feet, leaving 100 feet as the utmost possible depth of the water at the brink of the fall; this would give but five feet for the depth of the American Fall, which surely is too little. I know of no observations to show that the velocity at the one fall is much greater than at the other, so that there remains only the unequal resistance in different directions of the strata collectively, to account for the remaining part of the effect, and this appears to be *required* to explain it, thus supporting what was already inferred from the rectilineal position of the four points, A, D, G, and F, that the rocks do resist unequally in two transverse directions. If we assume as above ten feet for depth of water at the American Fall, and a depth four times as great for that of the Canadian Fall, which does not seem extravagant, also a velocity at the latter fall twice as great as at the former, it would then require a resistance two and a half times greater in one direction than the other. Is this too great to be supposed? A still greater relative resistance to abrasion would be required if, instead of comparing the fall F H with the American Fall, we compare it with the other partial fall F G, unless we suppose in this last, a depth of water and velocity of flow, much less than in F H, which does not appear probable.

If the curved form of the Canadian Fall be regarded not as arising from the unequal resistance of the rock in different directions, but as the normal form throughout the course from A to G, it will still be true that the main fall has cut its path of nearly uniform width and direction, very nearly as though the American Fall did not exist, the vertex receding from B to F. The ratio of recess would then be as 40 yards to about 800 yards, or as 1 to 20, and reduced one fourth according to principles given above, would be as 1 to 15, which would

still require a resistance in the line of direction of the American Fall nearly twice as great as in the other, showing that the resistance was greater in one direction than in another, *at the American Fall*, if nowhere else.

Another mode of explaining the inequality of recession occurs to me; to suppose the effect produced by the volume of water is not proportioned to the volume simply, but to some power of the volume, as the $\frac{3}{2}$ power or the second power; but still the continuity of the line A D G to F, appears to me to require the supposition of a great inequality of resistance in transverse directions, since we cannot suppose any great inequality of depth or velocity in the two partial falls, F G and F H.

Good observations are wanting on the width, depth, and velocity of the streams at several points above the two falls, in order to estimate the volume of water passing over each, also of the velocity at or near the brink of each fall; then from the known volume, linear length of brink, known from survey, and the known velocity at the brink, the depth of water there might be computed for each, if required. The ratio of volumes of water compared with the ratio of recession would show how far inequality of resistance entered as a factor in the final effect.

Besides the usual modes of estimating the velocity of the stream, such as the space passed through in a given time by objects floating in the stream, etc., the following method might be practised, by observations on the parabola described by the cascades at different points. Direct the centre of the cross wires of a theodolite to the summit S of the curve of the cascade at a distance from the instrument known by survey, then turn the telescope through a known *horizontal* angle to the point O, then depress the telescope through a known *vertical* angle to a point P in the stream of water proceeding from S, then from these known angles, and the known depression of the points O and S below the centre of the instrument, and the distance of S, find the lengths of O S and O P in feet; then will the required velocity v at the point S, be given by the equation $v = \frac{4 \times OS}{\overline{OP}}$. The chief difficulty will be in determining the point S or vertex of the parabolic curve.

The points I have sought to establish in the preceding paper, on the supposition that the gorge is excavated by the action of the falls themselves, are the following:—

1. That, from the sameness of direction of the sides of the gorge above and below the American Fall, the main fall has cut its way to G independently of the existence of a lateral stream or fall.

2. That the recession of the main fall is not less than ten or fifteen times greater than that of the American Fall, and, therefore, that no deduction from the recession of the latter is applicable to the former, without modification.

3. That, if the volume of water at the Canadian Fall be not so much as ten or fifteen times greater than at the American Fall, (which is unknown, but does not seem to me probable,) the resistance to abrasion offered by the strata, in the direction of the gorge, must be less than in the transverse direction at the American Fall, perhaps not half as great.

4. That in consequence of the continuity of the line A D G to F, it is probable that the abrasion in the Canada Fall takes place chiefly along the line F H, and that the recession of this fall will be in the direction of the line F I, so that finally the line of brink of the two falls, Canadian and American, will be nearly the same, along the line A I, or one parallel to it.

Postscript. — Through the kindness of Professor Hall I have seen a copy of his note to be appended to my letter to him on the Falls of Niagara. Only a few additional remarks on my part seem to be required.

The use of the term *abrasion* may not have been judicious; I desired to express, not the wear of the rock by attrition or erosion, by the mere friction of the water, but the whole wear, waste, or removal of the rocky strata by the mechanical action of the water in motion, in whatever way it occurred; I do not find that geologists use any definite term to express the sum or result of these actions, nor does a more appropriate one present itself to me at this moment than the word *abruption*, to express it.

Before venturing to offer suggestions with relation to phenomena that I have not recently examined in person, I of course prepared myself by studying the accounts given by others, as is implied in my letter, and certainly did not omit to read carefully Professor Hall's account of the falls, and of the geological structure of the precipice, in the Report of the Fourth Geological District of New York, and indeed his map

and sections of the falls were constantly before me while writing; the dip and strike of the strata were known to me, as also the position of the latter, with relation to the line of brink of the different falls. It was, therefore, not unknown to me that the general direction of the gorge was transverse, or nearly so, to the line of strike, but I did not allude to this point, because the fact of unequal resistance to *abruption* in different directions was first to be proved, and because if proved, I did not see, nor do I now see, how it might depend upon the position of the line of strike.

By the phrase "unequal resistance to abrasion or abruption," I do not mean *unequal hardness or difference of texture or of structure* of the rock in different directions, but by it I intended to express the bare fact that the abruption of the rock proceeded faster in one direction than in another, after making due allowance for the difference in the volume of water, leaving the cause or reason of this more rapid progress, for further investigation.

I by no means hold myself pledged to support the hypothesis of "unequal resistance," because I have once offered it. If the view of Professor Hall be correct, that the dip of the strata southward gives an increase of depth and of volume of water, as the falls recede, sufficient to account for the more rapid progress in the direction F I, then the whole effect will be referred to the most obvious causes, the volume and velocity of the stream, and the hypothesis of unequal resistance will be unnecessary. In such case, I shall have no disposition to maintain that hypothesis, as I can have no reason for doing so. It does not, however, appear to me yet proved, that the increase of dip is sufficient to account for the difference in the rate of progress.

With what accuracy the depth of water on the falls can be ascertained from the rate of dip of the strata, or the particular stratum determined, that forms the bed of the fall, I cannot presume under present circumstances to judge.

NOTE — By Professor J. Hall. The points noticed by Professor Gibbes seem to me to be well taken. With regard to the *rate* of recession of the falls, no one can presume to have accurate data. The fact of recession is apparent, and proved by observation and historical records.

The general direction of the chasm or gorge from Lewiston to the Canadian Fall, is in the same direction as the dip of the rock. This will be seen by reference to the map. When the fall was at the line A A, of the accompanying diagram, its

elevation was about the same as the northern margin of the American Fall at the present time. Supposing the strata to have been previously unbroken on the southwest, every yard of recession in that direction would give a greater depth of water over the margin of the fall, by the rate of dip in the rocky bed. The recession in this direction, therefore, giving a constantly increasing depth of water, would give, also, an increased velocity along the slope above the fall, owing to the greater declivity.

Under these circumstances the recession of the gorge, in the direction of the Horseshoe Fall, would continually abstract a portion of the water flowing in the other channel. In order to be convinced of this, it would only be necessary to extend the chasm half a mile further in the direction of the dip to show that no water could reach the American Fall. This may be satisfactorily shown by a diagram.

The character of the upper beds of the Niagara limestone are in general so uniform, that we can scarcely conceive that a greater facility of abrasion is presented in one part than in another. We do not perceive any reason for supposing that the action of the same volume of water could have been more effective, when applied in the direction opposite to the dip, than when applied in an oblique direction. The recession could not have gone on to produce the American Fall, without giving a greater depth and increasing volume of water over the receding Canadian Fall.

If this view be correct, the gradual recession of the Canadian Fall in the direction of F I, is inevitable, since the depth and volume of water must constantly increase as the elevation of the fall decreases, until the whole is drawn to this channel.

It is not impossible that some inequality of surface may produce another fall, on the south side of Goat Island, similar to the American Fall.

It appears to me that the most certain mode of estimating the depth of water on the Horseshoe Fall, would be to calculate carefully the rate of dip in the bed of rock forming the first step in the precipice. This, if accurately measured, for a few hundred yards below the fall, and its rate ascertained, would give the means of ascertaining the amount of dip after passing beneath the water and the farthest point of the fall. With this determined, the elevation of the surface of the water above the face, from any point on this rock below the fall, would determine the depth. The depth of water over the unbroken table rock at the Horseshoe Fall, must be less than fifty feet, and is probably much less than that; while on the American Fall the water is very shallow. This is possibly more than five feet, but if the water were evenly distributed over the entire width of the fall, it would be less than five feet.

One fact should not be overlooked in regard to the resistance and abrasion of the rock at Niagara Falls. It is not by *abrasion* simply, of the upper limestone, that the falls recede. The limestone overlies a soft calcareous shale, which is easily affected by moisture and frost; and the erosion of this shale is constantly in advance of the limestone above, which remains as an overhanging mass, falling in huge masses from its own weight, and the pressure of the water above. This condition is sufficiently shown by the fact that persons walk behind the sheet of water and beneath the overhanging limestone. The support or platform beneath the feet, in this case, is a stratum of limestone beneath the shale, which, in some measure, supports the lower part of the shale, and projects into the water below the level of

the river at the bend of the Horseshoe, and is broken down in masses as the rock above is broken down.

The geological structure is fully explained in the Report of the Fourth Geological District of New York, and in the Journal of the Boston Society of Natural History, vol. iv. p. 106.

So far as regards the points sought to be established in Dr. Gibbes's paper, it appears to me that the first and second are clearly proved; — with respect to the third we do not agree, while the fourth I regard as mainly sustained.

I must still maintain, in opposition to the views of Mr. Desor, that the bed of the Niagara will continue to ascend as the falls recede, at a rate which will preclude for ever any drainage of Lake Erie. It does not appear necessary to repeat here the arguments in favor of this view.

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6. On the Broadtop Coal Basin in Central Pennsylvania. With a Map, by J. P. Lesley, of Philadelphia.

The first descriptions published of this small isolated semibituminous coal-field were necessarily very imperfect, mere notices of the fact of coal existing at several points within a radius of eight or ten miles, and of the reason why, namely, the existence of a deep synclinal in the heart of the Upper Silurian region, between Huntingdon on the Juniata, and Bedford Springs. After an examination of two months or more by Mr. Alexander McKinley, in 1838, a short statement of the general outline and supposed subdivision of the field into small parallel troughs, was engrossed by Professor H. D. Rogers in the Annual Report of the Geological Survey of the State; but it was impossible to say at that time, even how many beds of coal it contained, in what way the dynamic geology would develop itself, or what were the actual relationships existing between the carboniferous formation in this outlier, and in the main body of the bituminous coal-field, the edge of which along the summit of the Alleghany Mountains is about forty miles distant. In this condition, the author took up its study in the spring of 1855, and has made a nearly complete survey of the seventy or eighty square miles which it covers. The levels of over nine thousand points upon the mountain have been obtained, and the structure made out with a fair approximation to accuracy. In

another season, the economical operations on the mountain will be so multiplied, that the minutest features of structure will become known, and a complete discussion of the fossils be possible. The present paper is intended to present only the fact and method of my survey, with its three principal results.

1. It has determined that the succession of the measures is not different from the system made out in Western Pennsylvania and Eastern Ohio. There is a base of Carboniferous conglomerate lying upon the Red Shale, from one to two hundred feet thick, massive, homogeneous, ferruginous, seldom conglomeritic, except as a whole, but always in certain of its layers, much of it oblique in deposition, and presenting magnificent expressions of a cleavage nearly vertical, which often completely masks the stratification.

Over this is the series of lower coal beds, then the barren measures, and over all the Pittsburg coal bed, the beginning of the upper series. The purple shales of the barren measures are, however, wanting, their place being supplied by ferruginous sandy shales.

The coal beds are mostly identified with those of the head waters of the Ohio, not by limestone companions, for these are almost entirely absent, nor by beds of iron ore, which are rare, and on which, at any rate, little reliance can be placed, — but by their order in the series, by certain general characters, and by their relations to the two conglomerates, the one at the base of the whole system, and the other at the base of the middle member of the barren measures, a rock as wide spread as the true conglomerate, and known as the Mahoning Sandstone. In the heart of this rock is a workable coal bed, and between it and the lower conglomerate two others, with four or five smaller beds. The larger beds are from five to ten feet thick; the lesser ones from one to three. In the barren middle series, which is four hundred feet thick, are several very small seams of carbonaceous matter. The Pittsburgh coal, and two hundred feet of the upper coal series, with no workable beds as yet known, but with one thin limestone, the representative of the limestone of Greensburg, (there eighty feet thick,) occupy the four geologically highest summits of the basin, the whole thickness of coal-measures in which is about nine hundred feet.

2. The structural results of the survey are interesting, for they exhibit in cross section the whole basin, seven or eight miles wide,

divided by a main anticlinal into two principal troughs, and these subdivided into numerous narrow synclinals or swamps, by a system of [illegible] not parallel to it, but traversing the basins at a low angle with their sides, and issuing, as in the Wyoming and other coal-fields, into the Red Shale valleys, through the walls of conglomerate. The larger of these synclinals form north-eastward normal terminal knobs, overlooking the great Red Shale valley of Troughcreek, but south-westward flatten out along the crest of conglomerate, which runs very obliquely across them. Their strength, however, in the Red Shale has yet to be determined, and I suggest here that I know of no point of detail in structural geology more worthy of elaboration than this very difficult problem: of determining by a sufficient number of thoroughly worked out examples, the law of the changes undergone by our numerous systems of small anticlinals, wherever they pass out from the massive sands into the equally massive but more plastic clay formations. I well remember certain very curious geometrical speculations upon this point, of Mr. James D. Whelpley, nearly twenty years ago, which he was led into by his development of the geology of the Pennsylvania anthracite coal-fields, but which there was no possibility at that time of demonstrating, nor has there been since. I believe that the discovery of this law will be in a good degree the settlement of the question, whether the wave theory of H. D. Rogers, or the pressure theory of Elie de Beaumont is to be adopted.

In this connection the curves of a broadtop cross section are very significant. Looking south-west they appear thus:—

It will be at once perceived, that the *steep* slopes are commonly *opposed* to the *normal* direction; that is, face the south-east instead of the north-west, and to my eye, present every evidence of an origin purely compressive, and not of an origin due to fluid progression in either direction. In the Terrace mountain alongside, we have the only instance of overturn to the east which I remember to have seen. I believe that in this matter of the normal curve, we have been much misled by making our sections too large, by not measuring them care-

fully enough, by omitting the smaller flexures, or fusing them into the larger ones, and by allowing the eye to be captured by the grander features of the waved line which has thus fallen fancifully into rythmical sequences and series of advancing waves. Every continuous Appalachian cross section should be not only carefully measured in all its dimensions, but reduced to so small a scale that the genius of its curves from end to end can pass at once under inspection, and be discussed without prejudice.

The abruptness of some of these Broadtop anticlinals, compared with the general flatness and repose is very remarkable, and is to be explained so far as I can see, by nothing but side pressure. No faults have yet been discovered exceeding a foot or two; but crushes, etc. are numerous along the horsebacks. The coal is universally slipped but seldom crushed, and hitherto has been found not only hardest but thickest in the steep dips.

A very interesting fact connected with the formation of coal, requires more positive proof than I can at present give it, namely, that the sulphuret of iron *abounds in the synclinals*. Miners and engine drivers insist upon its truth that where the bed is inclined steeply, the coal is purer, and where it lies flat the coal is soft and comparatively rich in sulphur.

3. The Pre-carboniferous coal-measures beneath the Red Shale, are represented in this region by one or more beds of black slate containing a little coal. The subcarboniferous limestone and iron are also present, but not in much force.

I hope to be able to present at the next meeting of the association, a perfect map of the region, and at least one very large specimen of a vegetable plume, not from the red shale, but from the conglomerate, and some statement of the palæontology of the basin. As yet my attention has been too much engrossed by the details of topography and structure, to pay due regard to any thing else, nor am I competent to utter an opinion worth the consideration of fossil botanists, until the collections which I have begun upon the mountain shall have been studied by those who can arrive at respectable results.

7. Notes on the Geology of Middle and Southern Alabama. By Professor A. Winchell, Ann Arbor, Michigan.

During a residence in middle Alabama of something more than three years, I enjoyed occasional opportunities for observation upon the cretaceous and tertiary rocks of that State. By request, I present some of the results of my observations in that geologically interesting region. I cannot promise much that is new, but perhaps the recent developments of the great extent and richness of the cretaceous deposits of the United States will attach some degree of interest to what little I may have to add to previous information in reference to the southern bend of the great cretaceous belt.

My observations in Alabama have extended from Tuscaloosa through the counties of Pickens, Sumpter, Greene, Perry, Dallas, Wilcox, Marengo, Clarke, Washington, and Monroe, in all of which I have travelled by private conveyance, and almost everywhere preserved such characteristic fossils as presented themselves. I have visited all the localities along the Alabama, Tombigby, Black Warrior, and Cahaba Rivers that had been rendered famous by the researches of my predecessors, and have preserved sections of these and many others taken on the spot. I always kept notes in my carriage of every thing observed, and from these I extract what I am about to present. My geological travels have extended to the Carboniferous, Silurian, Cretaceous, and Tertiary formations, but my remarks will be confined to the two latter.

The accompanying geological* map exhibits at once the extent and the results of my observations. The following Section may convey some idea of the geological relations of this part of the State.

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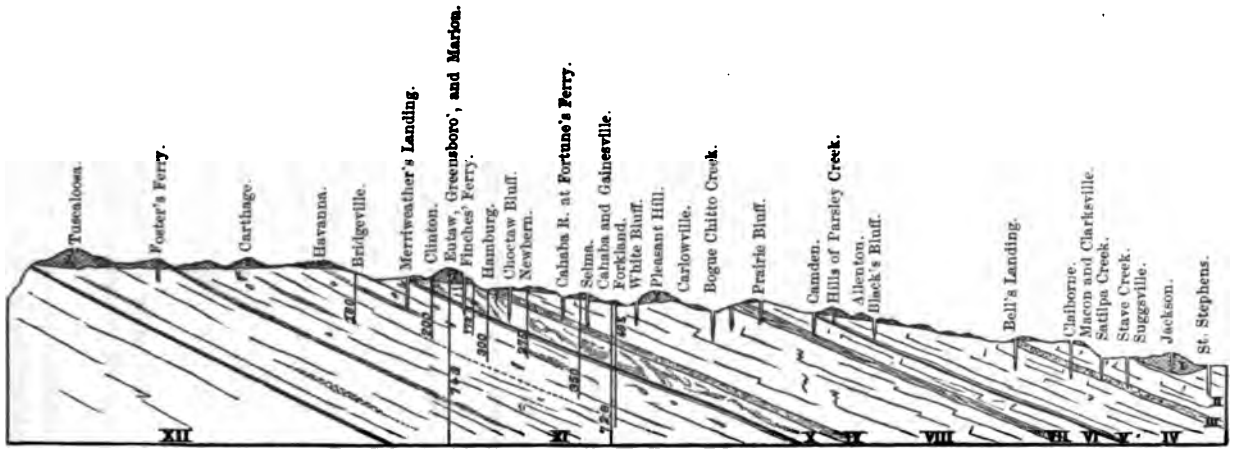
* Not published.



Section from Tuscaloosa to Eutaw, continued from Marion and Selma to Claiborne and thence to Jackson and St. Stephens, exhibiting the stratigraphical but not the geographical relations of the several localities, with true sections in miniature at all the principal Bluffs along the rivers and elsewhere, the whole the result of actual observation. By A. WINCHELL.

REFERENCES.

I. Superficial Materials.
II. White Limestone, } Upper Eocene.
III. Green Sand, }
IV. Buhr Stone, } Lower Eocene.
V. Buff Sand, }
VI. Prairie Bluff Limestone, }
VII. White Sand, } Upper Cretaceous.
VIII. Rotten Limestone, }
IX. Concrete Sand, } Lower Cretaceous.
X. Loose Sand, }
XI. Sand, Clay, and Shale.
XII. Carboniferous Rocks.

The vertical lines drawn across the above section show the location of some of the Artesian wells, with their depths annexed. For a notice of these and others, see paper entitled "Statistics of some Artesian Wells of Alabama."

The following table shows the principal strata which I have recognized, arranged in the order of superposition: —

I. Loam, Pebbles, etc.,	Superficial.
II. White Limestone,	Upper Eocene.
III. Green Sand,	
IV. Buhr Stone,	Lower Eocene.
V. Buff Sand,	
VI. Prairie Bluff Limestone,	Upper Cretaceous.
VII. White Sand,	
VIII. Rotten Limestone,	
IX. Concrete Sand,	Lower Cretaceous.
X. Loose Sand,	
XI. Sand and Clay,	
XII. Coal-Measures,	Carboniferous.
XIII. Dark Limestone and Slates,	Silurian.

Omitting for the present the superficial deposits, I propose to consider, in a descending order, the several strata enumerated: —

1. *The White Limestone.*

I shall not take the time to recapitulate what is already known of this or any of the succeeding strata. The researches of Lyell,* Tuomey,† Conrad,‡ and others have satisfactorily settled the relative age of the bluffs at St. Stephens and Claiborne, but I am not aware that any geologist has noticed anywhere the immediate juxtaposition of the white limestone of St. Stephens, and the continuation of the Claiborne sand-bed. Professor Tuomey, in his "First Biennial Report on the Geology of Alabama," p. 157, says: "It must be recollected that the Claiborne fossiliferous bed is nowhere found in absolute juxtaposition with the overlying orbilulites limestone."

In crossing from Jackson, below St. Stephens to Claiborne, I visited Stave Creek, about four miles north of the main road. This creek has formed high vertical bluffs at the bottom of a very deep ravine. At this place I had the satisfaction of seeing at top, the well known

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* Quart. Jour. Geol. Soc. Feb. 1, 1848.

† Rep. on the Geol. of Ala. p. 156.

‡ Jour. Acad. Nat. Sc. [II.] I. 112.

white limestone, full of the characteristic fossils, underlaid by bluish green sand filled with the Claiborne fossils, and at the base, a bed of shale precisely as at Claiborne, but destitute of fossils. On the land of Joseph Chapman also, a few miles west of Macon, (now called Grove Hill,) in Clarke county, some of the branches of the Satilpa Creek have excavated ravines to such a depth that in many places the Claiborne sand bed is exposed, while the white limestone caps the hills above. The sand in these places is quite blue and the fossils are very abundant and well preserved.

The limestone near the top of the bluff at Claiborne is undoubtedly the continuation of the white limestone of St. Stephens and Clarke county; though just at this point its mineral characters are not so well marked. This limestone is seen thinning out near the top of the bluff at Bell's Landing, a few miles above Claiborne. Below is the green sand bed with its familiar forms, while the lower half of the bluff is occupied by the dark shale, seen at the base of the Claiborne bluff. From the sand bed of this bluff I collected uncommonly large specimens of Turritella.

None of the writers on the white limestone, so far as I have observed, make any important distinction between the upper and lower portions. At St. Stephens, it is clearly separable into three sections. At the bottom of the bluff, the limestone is compact, gray, and intersected by firmly concreted bands. The characteristic fossil is *Plagiostoma dumosum*. This stratum has been nowhere else observed. The middle portion of the bluff consists of well characterized white limestone, containing *Pecten Poulsoni, Scutella Lyelli, and S. Rogersi*. The prolongation of this bed to Bettis's Hill, near Suggsville, contains abundance of *Ostrea panda*. The same is true of it at Claiborne. The upper portion of the St. Stephens bluff seems to me to present important points of distinction from other portions of the white limestone. It consists of strata of white hard silicious limestone. It is only in this portion of the bluff that *Orbilulites Mantelli* occurs. These silicious strata are seen capping the hills everywhere in the neighborhood. It is this portion of the bluff which is used for building, and some of the houses of the ancient, though now deserted settlement on the bluff, constructed of this material, are still standing. These same silicious strata are seen capping the hills around Joseph Chapman's, between Clarksville and Macon. They contain here,

besides *Orbitolites*, numerous sharks' teeth and spines of *Echini*, as well as fragments of branching corals. It is seen also on the summit of Bettis' Hill, west of Suggsville, and here contains the same fossils as in the latter place, while the zeuglodon limestone is readily recognized below, containing *Scutellæ*, *Pecten Poulsoni*, and *Ostrea panda*, quite a distinct group. For these reasons I would suggest the possible propriety of recognizing two stages of the white limestone.

2. *The Green Sand.*

I adopt this term from Professor Tuomey, though apparently this deposit would be better characterized as blue sand. This is the bed so celebrated by the labors of Conrad and Lea. As already stated, I have observed it in the beds of creeks near Macon, and in the bluff below the *zeuglodon* limestone on Stave Creek. It is also seen by the road side, a few miles east of Suggsville. The color of this sand is decidedly blue in its western prolongation, while toward the east, it becomes gradually more ferruginous, and at Claiborne, it is of a decided buff color. At Bell's Landing above, it is somewhat greenish. The palæontological characters of this deposit are well known, and I have nothing to add at present to previous knowledge. *Crepidula lirata* seems to be one of its most abundant and characteristic fossils everywhere except at Claiborne. *Ostrea Alabamensis* I have not found at Claiborne, while, in the interior of Clarke county, it forms extensive beds. The thick bed of limestone, which underlies the sandy belt at Claiborne, has not been recognized elsewhere. Perhaps its occurrence here is accidental.

Our geologists have generally spoken of the white limestone group as belonging to the Newer Eocene, while the green sand has been placed with the Older Eocene. I would not for a moment maintain an opinion discountenanced by the venerable and accomplished palæontologist, to whom we are so greatly indebted for our knowledge of American tertiary deposits, but I cannot help presenting here for consideration, the fact, that at Stave Creek, where I saw the *zeuglodon* limestone in immediate superposition above the green sand, I was able to trace in it obscure casts of the identical fossils of the latter. Among others which were too indistinct to identify, I saw *Turritella Mortoni* and *Candita planicosta*. Still, I must admit that these two fossils present a great vertical as well as horizontal range among the

Eocene rocks of Alabama, and their identification alone might not be considered sufficient ground for uniting the green sand to the St. Stephens Group of Conrad.* At any rate, the organic origin of the white limestone is clearly shown by these discoveries.

3. *The Buhr-stone Formation.*

Professor Tuomey, in his report already referred to, gives this name to the clayey, sandy, and silicified strata, which occupy the lower portions of the Eocene deposits of the Southern States. I present the observations which I have made upon these deposits in localities not particularly spoken of by others.

In passing from Macon, north-easterly, I saw by the road side and everywhere in ravines, about six miles from Lower Peach Tree, masses of chert or hornstone filled with silicified shells. These are accompanied by a light-colored clay. Similar beds are seen at intervals as far as the Alabama River, on the road towards Camden, but nowhere could I obtain a good view of the extent or mutual relations of these beds. Near the ferry, at Lower Peach Tree, are large masses of calcareous grit, containing *Turritella Mortoni*, *Cardita planicosta*, and other tertiary fossils.

Twenty-five miles east of the Alabama River, on the road from Monroeville to Allenton, I discovered beds of clay and grit, corresponding to those seen west of the river. At eight miles below Turnbull I attained a hill, descending which, I saw scattered along for a quarter of a mile numerous fragments of calcareous grit, very hard, and rendering the road exceedingly bad. In this, were noticed impressions of *Cardita planicosta*, and other fossils. Further down the hill, these gritty beds are underlaid by a fissile calcareous clay or rotten limestone. These beds are similar to what I saw below Lower Peach Tree, but I nowhere saw completely silicified shells.

The country along this road is exceedingly broken and covered with magnificent specimens of *Pinus palustris*. In the bottoms of the valleys, between the ridges, the pine disappears; the woody growth becomes more dense; the *Liquidambar*, the *Fagus*, the *Black Gum*, and superb *Magnolias* are found near the streams, while *Quercus nigra*, *Q. tinctoria*, and *Q. lyrata*, are noticed a little more remote on the ac-

* Proc. Acad. Nat. Sci. Vol. VIII. p. 257.

clivities. The evergreen flora is exceedingly rich. *Ilex*, *Cerasus Caroliniana*, *Gelsenium sempervirens*, and *Magnolia grandiflora*, flourish in the greatest luxuriance and beauty. The streams generally flow over pebbly beds, and the springs and wells furnish sweet and wholesome water.

Above Turnbull I noticed again at intervals, similar beds of calcareous clay or rotten limestone for a distance of eight miles, but I could find nowhere any included fossils. I saw similar beds twenty miles further west, above Black's Bluff. About eight miles from Turnbull, I came upon an areno-argillaceous limestone, somewhat hard, and strewing the road with fragments. I saw in these indistinct casts and impressions of shells. Between six and seven miles from Allenton, this rock comes to the surface, and fragments are strewn over the road for a considerable distance, making it exceedingly rough. A section is also exposed on a small stream near Fox's steam saw-mill. It comes to the surface again at five and a half miles from Allenton. At five miles I saw the rock again in its former soft state, containing more clay and less sand. The oak along here becomes more abundant as the pine diminishes in numbers. At one mile from Allenton, traces of the same rock are again seen near the surface and mingling with the "Red Loam." At half a mile below town, several sections show this rock distinctly in a laminar and scaly state. I traced these beds to town, where I saw fragments of the same mineral composition and firmly cemented, strewn over the surface, and noticed chimneys built of the same hard rock. About three fourths of a mile above Allenton, I discovered the origin of these hard fragments. Here occurs, on the east side of the road to Carlowville, a semicircular depression, surrounded on three sides by a range of hills, making a circuit of nearly a mile. All round the rim of this basin, and near the summit of the hills, is seen a shelf or ledge of rock, curiously projecting and conspicuous. On examination, it proved to be exceedingly hard. Beneath this ledge is a stratum of softer rock, composed of sand, lime, and clay, with scales of mica conspicuously shining. On examining the stratum I observed faint traces of shells for the most part too obscure to be certainly identified, but I could easily recognize casts of *Turritella Mortoni*. Two other casts were doubtfully referred to *Cardium* and *Cucullæa*. A short distance further on I discovered a most interesting outcrop of this sandy stratum consisting here of loose

materials. I was well repaid for a minute search in these sands by the discovery of a group of fossils, on the whole quite distinct from any elsewhere observed. Among them, however, were *Turritella Mortoni*, and others from the Claiborne group. The decidedly strange aspect of the collection, however, renders it probable that this sand represents a distinct stage in the Lower Eocene. The unrecognized species have been left with Professor Tuomey.

The overlying ledge of calcareous grit could be traced to a point eight and a half miles north of Allenton, which is some twenty-five miles further north than the tertiary beds have been hitherto recognized in this part of the State. From this point the landscape had a cretaceous aspect, but the vicinity of my route as far as Carlowville was deeply covered with sand, and I nowhere saw any fossils.

4. *Buff Sand.*

The strata of sand, clay, grit, and limestone, described above, are grouped together by Professor Tuomey under the designation of Buhr-stone formation. But I believe he had nowhere to the west of the Alabama River, observed the fossiliferous sand bed spoken of above, as lying at the very base of the tertiary rocks, and embracing shells and Echinoderms, which as a group are so distinct from the Claiborne fossils. It is this bed which, for the sake of a name, I designate as Buff Sand. I recognized it also fifteen miles further west in ascending a hill four miles below Camden. It is here cut through by the highway, and is seen to consist of buff and gray sand, showing oblique lamination, and variously intercalated with thin laminæ of blue black clay. Higher up the hill, it passes into a bed of buff-colored sand, full of fossils in a friable state, — tertiary beyond doubt, but too imperfect for recognition. Beyond this point, and seven and a half miles south of Camden, the same soft argillaceous limestones are seen, as overlie the buff sand between Allenton and Turnbull.

Still further on, in the section at Black's Bluff, I had the satisfaction to see both these beds in juxtaposition above, with cretaceous limestone at the base of the bluff. This bluff (No. 5) consists of red loam and pebbles at the top, which are strown down the sloping declivity. Beneath this is a thick bed of marly clay, soft and finely laminated, presenting precisely the characters of the rock seen between Turnbull and Allenton. Next below is a thin stratum of white

limestone. Next, a thick bed of buff-colored sand, so obscured by detritus from the top of the bluff, that I was unable to explore it. Finally, at the base of the bluff, is a bed of sandy limestone, containing abundance of a species of oyster, which I supposed to be cretaceous.*

The relative position of this bed of buff sand, as observed at Black's Bluff, and in the hill below Camden, shows it to be a prolongation of the sand bed seen above Allenton, and which affords a group of decidedly distinct tertiary fossils. For the reasons above given, I speak of the buff sand as a distinct deposit, older than the buhr-stone of Professor Tuomey, and lying absolutely at the base of the tertiary rocks of the State.

5. *Prairie Bluff Limestone.*

This is the limestone exposed at the top of the section at Prairie Bluff (No. 6). I have not been able to identify it certainly with the sandy limestone at the base of Black's Bluff. This limestone at Prairie Bluff is six feet thick, and white. It embraces in its upper part a bed of dark-colored, disintegrated limestone, four feet thick, containing obscure casts of fossils; the lower portion abounds in them, and the base is almost entirely made up of *Exogyra costata* and *Gryphæa mutabilis*, in a very fine state of preservation. Besides these, the following fossils come from this limestone, namely: *Gryphæa convexa*, *Placuna scabra*, *Turritella Mortoni*, *Voluta Sayana*, *Scaphites Conradi*, *Nautilus Dekayi*, three species of *Hamites*, *Pecten 5-costatus*, *Trochus leprosus*, *Plagiostoma gregale*, *Ostrea plumosa Echinodermata*, and teeth of placoid fishes. This limestone is well exposed, in a ravine a few rods west of the bluff, as well as at Shell Creek, one mile west. It is also seen in a section made by a stream two and a half miles north. It is exposed by the road side above Carlowville, near the ford over Cedar creek. I have not seen tertiary beds in immediate superposition above this, but I presume the Prairie Bluff limestone is the equivalent of the Black's Bluff limestone, and is the uppermost member of the cretaceous series of Alabama.

6. *White sand.*

This deposit immediately underlies the limestone at Prairie Bluff.

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* Professor Tuomey has since informed me that he regards this as a tertiary species.

It consists of a bed of loose, light-colored sand, about forty-five feet thick, intersected irregularly by bands of cemented sand. Its most abundant fossils are, *Ostrea larva*, (*falcata, Morton,*) *Pecten 5-costatus*, *Gryphæa vomer*. This bed also is well exposed at Shell Creek, and at the stream two and a half miles above the bluff. It is seen near the surface at Rocky Bluff, one mile above, and abounds in the same fossils as before mentioned, though the Pectens are better preserved here than I have seen them elsewhere.

A bed of white sand intersected in a similar manner by concreted bands is seen at the surface, some thirty miles farther east, in the neighborhood of Pleasant Hill. Major Vassar showed me whetstones of good quality, which he had manufactured from these belts of sandstone. I have seen no fossils certainly referable to the sand in this vicinity, but Major Vassar described a fossil which I recognized as *Spherulites*, which is so abundant in the neighborhood, that wagon loads of these, and oyster shells, are often hauled together and burned for lime. I have myself seen magnificent specimens of *Spherulites* collected a few miles farther south; and at Prairie Bluff I obtained valves of *Exogyra costata*, five inches in diameter, and of *Gryphæa mutabilis*, seven inches across.

7. *Rotten Limestone.*

I consider the rock at the base of Prairie Bluff, as the uppermost portion of this stratum, though, from its being at present covered with detritus from above, and overgrown with grass, it is difficult to explore it at this place. Being much more coherent than the superincumbent strata, the latter have been denuded during periods of high water, while the silicious stratum at base is left in the shape of a sloping platform. A few miles above Pleasant Hill, on the Selma road, it is beautifully exposed in ravines; and I collected here the largest and best preserved specimens of *Ostrea plumosa* that I have seen. This limestone, with its characteristic fossils, is finely exposed in the cuts made by the Chilatchee and Bogue Chitto Creeks above Prairie Bluff. It is also seen at the high bluff at Centerport, on the Alabama River, where it contains *Cucullæa*. The inclined plane at White's Bluff is cut through this limestone; it constitutes the bluffs at Cahaba and at Selma; and generally, the streams in all this region have formed deep, perpendicular cuts through this limestone. It forms the basis of

the prairie region of this part of the State; and its characteristic fossils were first brought to light by Conrad,* who examined it in the bluff at Erie, and other localities in Greene county. Being well known, I have nothing to add to the citation of the above localities.

8. *Concrete Sand.*

This stratum is well exposed at Choctaw Bluff, (No. 7,) on the Black Warrior river, six miles below Eutaw, in Greene county. I have described this bluff in the Proceedings of the Cleveland meeting of this Association. This stratum consists of sand cemented by carbonate of lime. It nowhere exceeds two or three feet in thickness, but in consequence of its uniform occurrence everywhere beneath the rotten limestone, I describe it as a separate stratum. At Choctaw Bluff, and in many other localities, it is little else than a compact mass of *Ostreidae* and fish teeth. The section at Fortune's Ferry, on the Cahaba river, may be mentioned as very similar to that at Choctaw Bluff, though sixty miles distant. Half a mile east of the village of Hamburgh, Perry county, is also a locality where this stratum crops out, and is an excellent place for the collection of shark's teeth.

9. *Loose Sand.*

This is a bed of yellowish gray sand, fifteen feet thick, at Choctaw Bluff, and much thicker at Finches' Ferry, a few miles above, where it occupies the upper portion of the section. It is not rich in fossils, but at Choctaw Bluff it abounds in fossil drift wood often completely riddled by the fossil *Teredo tibialis*. Professor Tuomey † states, that at Finches Ferry he has found *Ammonites Delawarensis* in this stratum.

10. *Sand and Clay.*

The bed of loose sand at Choctaw Bluff and elsewhere, is underlaid by a few inches of green sand of variable thickness. In the ravines at Mesopotamia, in Greene county, this green sand is advantageously studied. I have found here, between included laminæ of dark shale, the remains of vegetables appearing like the stems and

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* Morton's Synop. Organ. Rem. Cret. Group U. S. p. 21, etc.

† Report on the Geology of Alabama, p. 118.

leaves of dicotyledonous plants. Still lower in the series we find strata and thin laminæ of dark pyritiferous shale, alternating with very thin seams of green, gray, and ferruginous sand. These alternations are well seen at the base of the bluff at Finches' Ferry, (No. 8,) and throughout the whole extent of the bluff at Merriweather's Landing, a few miles higher up the river. The obscure remains of vegetables occur everywhere in the scanty seams of sand throughout this series. The same strata are frequently exposed in the cuttings for the highway between Eutaw and Tuscaloosa.

At about eight miles above Eutaw, the shale becomes softer, the lamination disappears, and we have beds of light clay mottled curiously with blue, red, and yellow, reminding one forcibly of the Keuper of the Germans. More than this, we find along the road sides and the margins of ravines in the upper part of Greene county, large masses of red and poikilitic sandstone, exceedingly compact, and used for underpinning buildings. Add to this that very many of the Artesian wells in Greene county, which penetrate these beds, furnish a constant flow of salt water, showing the occurrence of local deposits of salt; while the deepest borings have brought up abundance of quartzose pebbles, and we have four well-established facts compatible with the supposition of the *triassic* age of these beds, without mentioning the occurrence of vegetable remains, some specimens of which appeared to me indistinctly allied to stems of *Equisetites*.

These beds continue without much change to the very suburbs of Tuscaloosa; and a very good section is seen at Foster's Ferry, within a few miles of town.

The almost total absence of organic remains from these shaly and poikilitic deposits, renders the determination of their age extremely uncertain.

I desire in closing, to record my great obligations to Professor Tuomey, for the kindness which he has at all times shown me, and for the facilities which he has afforded me for the study of the geology of Alabama; and to express the hope that the legislature of that State will place it in his power to complete satisfactorily the survey which he has in charge, and to work out the results in as scientific and beautiful a manner as he is now doing, in conjunction with Professor Holmes, for the survey of South Carolina.

8. Statistics of some Artesian Wells of Alabama. By Professor A. Winchell, of Ann Arbor, Michigan.

I. The alternating beds of sand and shale which underlie the well known "rotten limestone" of the cretaceous series of Alabama, comprise the water-bearing strata of the region of the Artesian wells of this State. The general surface of the state gently rises along a line at right angles with the strike of the cretaceous rocks, so that the lower members of the series outcrop at successively higher levels. In the borings for Artesian wells, water is always obtained when water-bearing strata are pierced, whose outcrop is at a higher level than the point of boring. In individual cases, however, the water has failed to rise to the surface in consequence of the local elevation of the site of the well. In such cases, other borings in the immediate neighborhood, being situated at a lower level, have been successful.

The majority of these wells are situated within a few miles of the line of junction of the "rotten limestone," and the subjacent strata. On the limestone side of this line, the depth of the borings increases with the distance of the well from the line, — varying in this manner from one hundred to nine hundred feet and upwards. On the opposite or northerly side of the same line, the depth of the boring varies from two hundred to one thousand feet, in a manner which seems to depend on the local elevation of the place of excavation.

It would be interesting, and perhaps instructive, to enter into a description of the implements and machinery employed in the boring of these wells, but space does not permit.

The geographical and geological positions of a number of wells are given in a tabular form below. In the separate columns are found the depths of the respective wells, the quantity of water discharged, and its temperature at the surface. At the end of the table are found some additional statistics relating to some of the wells.

An examination of the Section on page 83 may help to convey an idea of the geological positions of some of the principal wells enumerated.

II. Table of Artesian Wells in Middle Alabama.

No.	Depth. ft.	Gal. w. per min.	Temp. Fah.	Location.
1	470		72	Junction of Main and Water sts. Selma. Limestone.
2	380	100	68	Main st. N. of No. 1. "
3	334	40	67	" N. of No. 2. "
4	280	12	67	Residence of Abner Jones, Esq., Selma. "
5	330	25		" " J. Lapsley, Esq., " "
6	409	230	67¾	Foundry, Selma; slightly chalybeate. "
7	360	300?	67	Machine shop, Selma. "
8	340	100		Hall's, " "
9	350	300	67	Russell & Berry's brickyard, E. of Selma; chalybeate. L.
10	360	300	66½	Harrison's " " Limestone.
11			67½	Blevins and Edwards, Selma. "
12	275	20		Plantation of E. P. Watts, Esq., near Selma. "
13	560	250		" of Freeman King, Esq., 5 m. below Cahaba, on
14	560	250		the E. bank of Alabama River. L.
15	728	1200	77½	The "Great Well" at Cahaba. L.
16	90		64	Finches' Ferry, Greene Co., above margin of Limestone.
17	258?		68¼	Johnston's mill, Finches' Ferry.
18	285		64½	Dr. Wither's mill, Greene Co. L.
19	360		65	" " " "
20	415		68	Boligee, " "
21	420		66	Dr. Wither's mill. L.
22	468		66½	" " "
23	522		70	Canefield, Boligee, Greene Co. L.
24	560		71	Capt. Johnston's, Finches' Ferry.
25	544		70	Dr. Perrin's, Burton's Hill, Greene Co. L.
26			72	Dr. Clement's, road side, 4½ m. S. of Eutaw. L.
27				Norwood & Cole, 14 m. S. W. of Eutaw. Highly saline. L.
28			70½	Col. Pickens, Warrior river, 4 m. S. " " "
29	180		69?	Col. Johnston's horselot, Finches' Ferry, Greene Co., above Limestone.
30	420			J. W. Hall's plantation, 12 m. S. of Eutaw. Limestone here about 350 ft. thick, 12 m. from its margin.
31			70	Mr. L. Duffin's, Newbern, Greene Co. Highly saline. L.
32	294	3	68¾	Livingston's, Hamburg, Perry Co. ¼ m. above edge of L.
33	294	20	68¾	Howell's " " "
34	330	100	69	Weaver's mill, " " "
35	352	100	69	" " " "
36				Public well at Eutaw, Greene Co., ¼ m. above L. See Remarks.
37			69¾	Dr. Clement's 2d well below Eutaw. Saline. L.
38	200		67½	Cleaveland's, Springfield, N. of L. Water was reached at 190 feet.
39	555		75	Court House well at Cahaba. L.
40	400		73¾	Bell's (Hotel) well " "
41	456		72½	S. L. Creswell's, 10 S. W. of Eutaw, near his house. L.
42	440		71	Well in the field at Creswell's plantation. L.
43	550		72½	Half mile N. of No. 41, Creswell's. L.
44	495		72½	Williamson Glover's, Greene Co. L.
45	216		67	Dr. Childer's, 5 miles W. of Selma. L.
46	394			Mr. Strait's, ¾ m. W. of Clinton, above L.
47	150			Dr. Cochran's, Sipsey river; above L.

No.	Depth. ft.	Gal. w. per min.	Temp. Fah.	Location.
48	120			Mr. Craft's; above. L.
49	281			Mrs. Barry's; "
50	415			Mr. Raspberry's 1st well; above Limestone.
51	260			Mr. Campbell's, "
52	310			Dr. Brackett's, "
53	240			Maj. Whitsett's, "
54	276			Dr. Rogers' near the house on his plantation W. of Clinton. Ib.
55	400			Dr. Rogers' plantation, Clinton, Greene Co. Ib.
56	300			Mr. Smith's; above the Limestone.
57	404			Dr. Hutton's; " " "
58	280			John Thompson's 1st well.
59	300			" " 2d "
60	360			At the church in Clinton, Greene Co.; above L.
61	348			Maj. Barry's " " "
62	340			Dr. Wille's, " " "
63	336			Public Well, " " "
64	300			Mr. Brown's, " " "
65	350			Mr. Copp's, " " "
66	310			Mr. Walker's, " " "
67	280			Mr. Sears', " " "
68	180			Public well at Bridgeville, Pickens Co., above L.
69	415			Warsaw, Sumpter Co. L.
70	300			Mr. Taylor's, below Warsaw. L.
71	380			Peter Ware's, 7 m. W. of Warsaw. L. 1st well.
72	360			" " 2d well.
73	400			Maj. Whitsett's, W. side of Bigby. L.
74	600			D. White's, Cooksville, Noxubee Co. Miss. L.

III. *Remarks.*

Nos. 1 to 11. These wells are in and about the city of Selma, within a distance of two miles from the foot of Main (Broad) street. The temperature of *common* well water, taken at the same time with the temperatures of these wells, was sixty-four degrees. The authority for the depths and quantities of water discharged from these wells, is Mr. Crow, who has executed the boring of all the Selma wells, except the one at the foundry, which was bored under the superintendence of Mr. Campbell.

The following is Mr. Crow's statement of the borings of well No. 1:—

(1)	Clay, sand, and gravel	27	ft.	
(2)	Blue rotten limestone	53	"	
(3)	Sandstone	6	"	
(4)	Gray sand with water	6	"	
(5)	Blue clay	18	"	
(6)	Blue sticky sand	24	"	
(7)	Blue clay	17	"	
(8)	Green sand	4	"	
(9)	Gray sand with water	42	"	5 inches.
(10)	Green sandstone			11 "
(11)	Blue clay	3	"	
(12)	Gray sand with water	54	"	3 "
(13)	Sandstone			7 "
(14)	Blue, grayish sand, with water frequent; beds of blue clay 5 to 10 feet thick	213	"	10 "
	Total depth	470	"	

Size of the bore, 6 inches; tubed 400 feet.

It may be interesting to know that the wells, Nos. 2 and 3, were first bored, and that the boring of No. 1 materially diminished the flow of water from the former two. These three wells are within the distance of one third of a mile.

Mr. Campbell, who bored the foundery well, No. 6, and is said to keep a register of all his borings, has furnished for No. 6 the following results: —

(1)	"Red loam, clay, sand, and pebbles	372	inches.
(2)	Rotten limestone	420	"
(3)	Soft sand rock ["Loose sand"]	48	"
(4)	Concrete of sand and shells. ["Concrete sand"]	6	"
(5)	Green sand	24	"
(6)	Gray sand and water	72	"
(7)	Hard sand rock	3	"
(8)	Sand and shells	132	"
(9)	2d hard rock	9	"
(10)	Green sand	12	"
(11)	Rotten limestone. [See below]	48	"
(12)	Blue sand, fine and firm	288	"
(13)	Green sand and water	—	
(14)	Rotten limestone. [See below]	180	"
(15)	Green sand and water	84	"
(16)	Sticky blue sand and clay	144	"
(17)	Green sand	36	"

(18)	Gray sand and water	204 inches.
(19)	Green sand	48 "
(20)	Brown sand and water	60 "
(21)	Sand rock	6 "
(22)	Gray sand	12 "
(23)	Sand rock	36 "
(24)	Gray sand and water	48 "
(25)	Green sand	24 "
(26)	Laminated clay	12 "
(27)	Gray sand	—
(28)	Green sand and water	168 "
(29)	Rotten limestone, [see below]	12 "
(30)	Gray sand	—
(31)	Green sand	168 "
(32)	Rotten limestone, [see below]	24 "
(33)	Gray sand	280 "
(34)	Green sand	120 "
(35)	Rotten limestone, [see below]	108 "
(36)	Spanish-brown colored sand	72 "
(37)	Blue clay and sand	420 "
(38)	Gray sand	— "
(39)	Brown sand	72 "
(40)	Green sand and water	36 "
(41)	Gray sand and water	204 "
(42)	Blue sticky clay and sand	96 "
(43)	Sand rock	25 "
(44)	Spanish brown sand	96 "
(45)	Blue sticky clay and sand	72 "
(46)	Green sand and water	168 "
(47)	Gray sand and water	—
	Total depth	409 ft.

The strata designated as "rotten limestone," in (11), (14), (29), (32), and (35), above, are undoubtedly strata of light colored and perhaps calcareous clay.

The Alabama River rises at Selma in time of flood, 65 to 70 feet. The city stands 10 feet above high-water. The average expense of boring the Selma wells to the depth of 350 feet is not far from 350 dollars. There are now (1853) in Selma and Cahaba, and the intervening country, some 25 or 30 Artesian wells.

No. 12. This is one of the few wells on the east (left) side of the Alabama River. It is nearly opposite Cahaba, and was bored by Messrs. Crow and Read.

No. 15. Mr. Campbell, who bored this well, has furnished the following register of borings: —

(1)	Loam, red clay, sand, and pebbles	394 inches,
(2)	1st. Rotten limestone	3970 "
(3)	1st. Sandstone (a concrete of sand and shells)	6 "
(4)	Gray sand with water	36 "
(5)	2d. Sandstone	15 "
(6)	Gray sand	29 "
(7)	Sticky sand and clay	117 "
(8)	Sand and rotten limestone (?) [Clay]	93 "
(9)	Sticky sand and clay	237 "
(10)	Green sand	18 "
(11)	Gray sand with water	1558 "
(12)	3d. Sandstone	11 "
(13)	Gray sand with water and streaks of rotten limestone (?)	612 "
(14)	Bluish gray sand with two streaks of reddish sand	384 "
(15)	Bluish gray sand and laminated clay	330 "
(16)	Dark gray sand with water	312 "
(17)	Bluish gray sand and clay with water	716 "
	Total depth of well	727 ft. 11 in.

and throws out 1,200 gallons of water per minute.

This is truly an astonishing well, but I am sceptical in regard to the alleged quantity of water discharged. Supposing the orifice to be 12 inches in diameter, which I believe exceeds the truth, a discharge of 1,200 gallons per minute would require a velocity of 204 feet per minute, and this velocity by the laws of hydraulics necessitates an ascent of nearly 22 inches; whereas the stream does not rise 12 inches above the mouth of the pipe. As the well, however, is now in a greatly exposed condition, it is not improbable that the bore has been somewhat choked by the mischievousness of boys, whom I have seen throwing brickbats down for amusement. The well was originally bored for the purpose of supplying a steam factory, but is now entirely unemployed.

Nos. 18 to 25. The facts relative to these eight wells are copied from Tuomey's Geological Report. The two at Finches' Ferry, 16 and 17, are beyond the edge of the limestone. "The water is generally highly charged with salts of lime, magnesia, soda, and iron, and in some instances it is impregnated with sulphur." (Tuomey's Report.)

So far as my observation extends, *all* the wells in Newbern, Greene county, are strongly charged with sulphuretted hydrogen. The water from Colonel Pickens' and Dr. Clement's wells (Nos. 26 and 28), and others, are very highly saline.

No. 26. A chemical examination of the water of this well showed it to contain large quantities of chloride of sodium with small additional quantities of salts of lime, magnesia, and iron. The considerable quantity of free carbonic acid present gives the water an unusually lively taste, and it begins to enjoy some little repute as a medicinal water. Indeed, it is difficult to distinguish it by the taste from the celebrated "Congress water."

Nos. 32 to 35. These wells are situated a few rods above the outcrop of the rotten limestone.

No. 36. This well has been more than two years in progress [written in 1853], and though a depth of over 700 feet has been reached, no water has as yet risen to the surface. The situation is just beyond the margin of the "rotten limestone." At less than 100 feet water was reached which came within a few feet of the top. Undoubtedly the failure of this well is owing to the slight elevation of Eutaw above the surrounding country; for, at Judge Evans's, less than half a mile further south, and just over the edge of the limestone, is a successful well though not copious; while at Finches' Ferry, four miles distant, are several copious wells, occupying about the same geological position as the one at Eutaw, though situated at a considerably lower level.

The following statement of the borings of this well has been furnished by John W. Elliott, Esq., the superintendent of the work:—

(1)	Soil and red clay	15 feet.
(2)	Sand and soft light colored, mottled clay — last foot laminated	45 "
(3)	White sand and water	3 "
(4)	Blue shale and yellowish clay alternating in thin layers	200 "
(5)	Yellowish clay inclining to red	130 "
(6)	Red, caving soil crumbling like rotten brick	100 "
(7)	Sand (and water) brown, white, and greenish	20 "
(8)	Red and yellowish clay	100 "
(9)	Dark brown sand	50 "
(10)	Coarse reddish sand with gravel and scales of mica	80 "
(11)	Reddish "soapstone" — like bed of clay	— "
	Total, August, 1853,	743 feet.

No. 41. Diluvial materials here, 11 feet thick; limestone, 200 feet thick.

No. 55. At 140 feet from the surface a hard sand-rock was struck which continued 3 or 4 feet.

Nos. 46 to 74. These wells are mostly situated a short distance beyond the junction of the rotten limestone and subjacent strata. Their depths are given on the authority of Mr. James Strait, well-borer of Clinton, Greene county. The strata penetrated are perfectly similar to those whose statistics have already been given. Generally, in the valley of the Sipsey river, the wells are from 150 to 200 feet deep. At Vienna, at the mouth of the Sipsey, they vary from 350 to 400 feet.

IV. *Increase of Temperature.*

The Artesian wells of Alabama are not particularly adapted to furnishing exact indications of the rate of increase of temperature. As the water generally enters the well at several different points, the temperature of the mixture taken at the top, will always be more or less *below* that of the deepest water reached. The temperatures observed, therefore, in the different wells may vary considerably *below* the true temperature of the deepest seated water, but cannot vary *above* it. Those observations, therefore, which indicate the most rapid increase of temperature are most likely to serve as reliable data.

The mean annual temperature of that part of Alabama over which these wells are distributed, is not far from 64° Fahr., and this is the temperature of ordinary well-water at Selma. The point of constant temperature within the earth's crust has been fixed by different authorities at 50, 60, 70, and 80 feet beneath the surface. As the annual extremes of Alabama are considerable, the point of constant temperature may perhaps with propriety be placed at 80 or 90 feet. Calculating the results from these data, I have formed the following table: —

No. of Well.	Depth feet.	Temp. Fahr.	Temp. above 64°.	CONST. TEMP. 90 FT.		CONST. TEMP. AT 80 FT.	
				Depth below 90 ft.	Feet for 1 deg.	Depth below 80 ft.	Feet for 1 deg.
1	470	72	8	380	47.5	390	48.7
2	380	68	4	290	72.5		
3	334	67	3	240	80.0		
4	280	67	3	190	63.3		
6	409	67¾	3.75	319	85.0		
7	360	67	3	270	90.0		
9	350	67	3	260	86.7		
10	360	66½	2.5	270	108.0		
15	728	77⅓	13.5	638	47.2	648	48.0
17	258	68¼	4.25	168	39.5	178	41.9
18	285	64½	0.5	195	390.0		
19	360	65	1	270	270.0		
20	415	68	4	325	81.2		
21	420	66	2	330	160.0		
22	468	66½	2.5	378	151.2		
23	522	70	6	432	72.0		
24	560	71	7	470	67.1		
25	544	72	8	454	56.7	464	58.0
29	180	69?	5	90	18.0		
32	294	68¾	4.75	204	42.9	214	45.0
33	294	68¾	4.75	204	42.9	214	45.0
34	330	69	5.00	240	48.0	250	50.0
35	352	69	5	262	52.4	272	54.4
38	200	67½	3.5	110	31.4	120	34.3
39	555	75	11	465	42.3	475	43.2
40	400	73¼	9.75	310	31.8	320	32.8
41	456	72½	8.5	366	43.0	376	44.2
42	440	71	7	350	50.0	360	51.4
43	550	72½	8.5	460	54.1	470	55.3
44	495	72½	8.5	405	47.6	415	48.3
45	216	67	3	126	42.0	136	44.0

Mean, 46.5.

In the fourth column of the preceding table I have given the excess of the observed temperature of the water above 64°. In the fifth column are the depths of the wells below the point of constant temperature, assuming this at 90 feet below the surface; and in the sixth column is the number of feet in depth corresponding to one degree of increased temperature.

Since the higher numbers in the sixth column are, for reasons already stated, most likely to be erroneous, I have entirely rejected those results which exceed 100 feet and also the 29th observation. The general mean of the residue is an increase of temperature of one degree for every 56.7 feet. If we still further reject all numbers in the sixth column which exceed 60 feet, the result obtained is one degree for every 44 96 feet.

If we suppose the point of constant temperature to be situated at 80 feet instead of 90 feet beneath the surface, and employ the same set of observations as last-mentioned above, the rate of increase deduced therefrom is one degree for every 46.5, feet as shown in the seventh and eighth columns of the table.

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9. On the Agency of the Gulf-Stream in the Formation of the Peninsula of Florida. By Joseph Le Conte, of Athens, Georgia.

In the winter of 1851, and during the months of January and February, I enjoyed the rare opportunity of visiting and examining the keys and reefs of Florida, in company with Professor Agassiz. I then and there became deeply interested in a subject which has continued to occupy my thoughts from time to time until now; namely, the mode of formation of the Peninsula of Florida.

Until the time referred to, nothing definite was known of the geology of Florida, but it was supposed to consist of a southward prolongation of the eocene of Georgia and Alabama, and its shell-limestone to bear some general resemblance to the white limestone of these States. But the observations of Professor Tuomey,* during the summer of 1850 and the more full and careful observations of Professor Agassiz,† during the following winter, brought to light the remarkable fact that the keys, and the larger portion of the peninsula of Florida are of recent origin, and as far as could be examined, the work of corals — still living in the vicinity, and still engaged in the work of extension — that they are in fact, superficially, at least, the result of the growth of successive coral reefs concentrically arranged, one outside of the other, from north to south. My object in the present paper will be to show that coral agency alone is not sufficient to account for the phenomena, but that there has been another and still more powerful agent at work preparing the ground and laying the foundation for these builders; and that this agent has been the *Gulf-Stream*. A clear understanding

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* Silliman's Journal, 2d Series, Vol. II. p. 393.

† Report of Coast Survey for 1851, p. 145.

of the subject renders necessary a succinct account of the views of Tuomey and Agassiz.

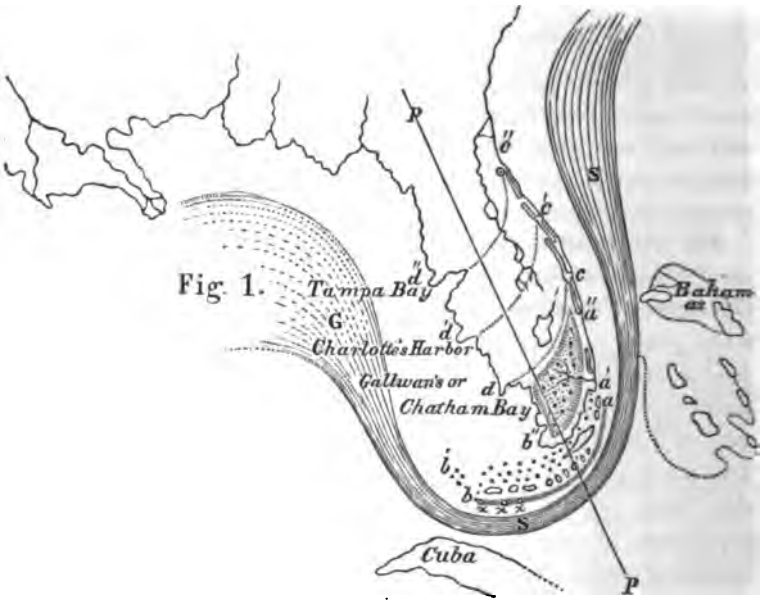


Fig. 1 represents the peninsula and keys of Florida; a'' b'' the southern coast; a' b' the line of keys, a b the line of living reef; G ss the Gulf-Stream sweeping around the living reef. Between the living reef a b and the line of keys a' b' there is a ship channel varying from five to ten miles in width, and three or four fathoms deep. Between the southern coast a'' b'' and the line of keys a' b', a distance at the point b'' of about forty miles, the water is very shoal, navigable only for the smallest fishing craft, and dotted over with small low mangrove islands. The southern coast is about twelve or thirteen feet above the sea. Within the southern coast, however, we have the everglades, a low swamp but a few feet above the level of the sea, covered with fresh water and dotted over with small islands called hammocks. Beyond, the living reef at the sea bottom slopes rapidly into the almost unfathomable bed of the Gulf-Stream.

Now we have the best evidence that the everglades, the southern coast, and the keys are all formed by coral agency. The evidence is briefly as follows.

It is a well-known fact that corals cannot grow above the surface of

the water. The islands therefore so commonly formed on coral reefs cannot be formed by the agency of these animals alone, but are due to the violent action of waves breaking off huge coral heads and overturning coral trees, bearing them from the outer and more exposed side and piling them on the middle and inner side of the reef. These coral boulders form the nucleus around which cluster smaller fragments and coral sand; the whole is then firmly cemented by carbonate of lime in solution in the sea-water, and the island thus formed is finally covered with vegetation and inhabited by animals and man.

The whole embryonic development, if I may use the expression, of coral islands may be observed upon the keys and reefs of Florida. On the outer or living reef *a b* some of these commenced to form only a few years ago, exist as yet only in the form of isolated boulders of dead coral, and are not yet dignified with the name of keys. Others are formed of similar boulders mingled with smaller fragments and coral sand, and firmly cemented by carbonate of lime, but the larger boulders are still conspicuous above the surrounding sand though immovably fixed. Still others are so covered with coral sand that the boulders are not observable, except by excavation or by examination of the outermost portion of the island towards the sea. The coral sand is always affected with the cross and oblique stratification so common in materials exposed to the violent action of waves. All the islands on the outer reef *x x x*, are very small, of very recent origin (some only a few years old) and therefore as yet entirely barren.

The examination of the larger and older inhabited islands of the line of keys *a' b'* proves beyond question that they have been formed in a similar manner. We have here also the same coral boulders mingled with smaller fragments and coral sand, and the whole firmly cemented into solid rock, the same cross or oblique stratification indicating the former action of waves on an exposed shore. The boulders here, also, sometimes stand above the surrounding cement, exposed in their superior portions, as at Key Vaca, and at others completely covered with coral sand, as at Key West and most other keys. This exposure of the larger boulders above the surrounding cement in which they are firmly fixed, led Tuomey into the error of supposing that they were the prominent points of the original reef elevated above the sea level by igneous agency, and that the keys were formed by igneous, rather than aqueous agency. That such is not the case is proved by more attentive examination and comparison with the smaller keys of

the outer reef. There can be no doubt, therefore, that the line *a' b'* is the position of a former reef changed into keys by the action of waves alone.

In a similar manner it has been pointed out by Tuomey and proved by Agassiz, that the southern coast *a'' b''* of Florida was the position of still another and an earlier reef. The character of the rock is the same as that of the keys of the main range or of the smaller ones on the living reef. Here also, Tuomey has seen, as he supposes, the evidence of elevating forces, while Agassiz sees nothing but the action of waves.

There seems to be no reasonable doubt, therefore, that at some former period the northern shore of the everglades *c. d.* was the position of the southern coast, and at the same time the present southern coast *a'' b''* was the position of a reef. The general sequence of changes has been as follows: *a'' b''* became gradually converted into a line of keys and finally added to the mainland, and the shoal water between *a'' b''* and *c. d.* became the everglades, and its mangrove islands the hammocks which overdot this swamp. In the mean time, *i. e.*, while *a'' b''*, the present southern coast, was still a line of keys, another reef was formed further out. This became in time converted also in the line of keys *a' b'*, and will eventually be added in its turn to the mainland, and become the southern coast, — the shoal water between *a'' b''* and *a' b'* with its mangrove islands becoming another everglade with its hammocks. In the mean time still another reef has been formed yet farther out, namely, the present or living reef *a b*, and upon this too, the process of key formation has already commenced. Any farther extension, however, in this direction, by the growth of still another reef, seems precluded by the proximity of deep water. Standing upon the reef, the blue waters of the Gulf-Stream are distinctly seen at the distance of but a few hundred yards.

Thus it appears that not only the keys but the mainland of Florida, certainly as far north as the northern shores of the everglades, has been formed, superficially at least, by coral agency. The evidence in favor of a similar origin for that portion of the peninsula lying north of this line is less abundant, and perhaps less conclusive. Yet we have every reason to believe that the greater portion of this also was formed in a similar manner. Although the geology of this part has not, as far as I know, been examined by any one capable of deciding definitively as to what portion of the peninsula is tertiary and what is recent coral

formation; yet specimens of coral rock precisely similar to that of the southern coast and keys, sent to Professor Agassiz from the shores of Lake George * and other parts of Florida, as far north as St. Augustine, leave no doubt that on the eastern coast at least, the coral formation extends as far north as that ancient city. I have myself a fragment of meandrina from the neighborhood of St. Augustine undistinguishable from fragments which may be picked up anywhere upon the keys. The western shore is still less known, but Conrad and Tuomey state their opinion that the bluffs of Tampa are eocence tertiary.† Supposing this to be a fact, though it is still problematical, then all that portion of the peninsula lying south of the line *c″ d″* is almost certainly of coral origin and formed in the manner already indicated, namely, by the growth of successive reefs. As to the position of these supposed reefs we know absolutely nothing. The position of the lines *c″ d″* and *c′ d′* has been merely suggested by the succession of bays which indent the western coast. May they not all have been formed like Chatham Bay, by the imperfect filling up of the shoal water separating successive reefs from the mainland?

Such is a brief account of Professor Agassiz' views concerning the mode of formation of the peninsula and keys of Florida. I will now attempt to show that coral agency alone is not sufficient for this purpose; and that the supposition would violate all probability, and contradict all that we know of the laws which govern the growth of these animals.

It is a well-known fact that reef-building corals cannot grow at a greater depth than from ten to twelve fathoms. It is also certain that they cannot grow above the surface of the water at low tide. Thus they are limited in a vertical direction to a space of about sixty or seventy feet. Unless there is subsidence of the sea bottom, therefore, it is impossible that a reef should be more than sixty or seventy feet thick. To this may be added, in the case of coral *islands*, from ten to fifteen feet for materials accumulated above the sea level by the agency of waves. If there is no subsidence, therefore, no coral formation can be more than eighty feet in thickness. Now nothing can be more certain than that there has been no subsidence whatever of the

* Types of Mankind, p. 352.

† Silliman's Journal, 2d Series, Vol. II. p. 393.

sea bottom upon which grow the reefs of Florida; for otherwise the extension of the peninsula by means of coral agency would have been impossible. It necessarily follows, therefore, that the coral formation of Florida, whether upon the mainland, or upon the keys, or upon the living reef, can nowhere be more than seventy or eighty feet thick. In other words it is evident that Florida and the keys are only faced or incrusted with coral formation. If then corals have been the only agents in this work; if the sea bottom has remained substantially unchanged during the whole time the coral work was progressing, it is evident that the sea for the enormous distance of five degrees of latitude, namely, from St. Augustine to the present reef was nowhere more than sixty or seventy feet in depth, and Florida must have been represented by a tongue of shoal water three hundred miles in length; a circumstance possible certainly, but so improbable, that it behooves those who maintain the theory that corals alone have formed the peninsula to account for it. But even if we admit the probability of such a condition of things, we do not get rid of the main difficulty, for in that case there is no apparent reason why the corals should not grow over the whole area at the same time, as an immense coral forest instead of in the form of successive reefs. In a word, the fact that the corals grew in the form of *successive* reefs concentrically disposed from north to south proves, as it seems to me, incontestably, that the conditions necessary for coral growth have also been progressively formed in the same direction. The horizontal extension of corals through so great a space proves also the progressive extension of the necessary conditions; in other words proves that the sea bottom has been gradually rising from the north towards the south.

Such a gradual rising of the sea bottom may be attributed to one of two causes, namely: first, gradual elevation by igneous agency; and secondly, filling up by sedimentary deposit. As we have already seen, Professor Tuomey has thought that there are evidences of such igneous elevation upon the keys as well as upon the mainland, but the more careful observations of Professor Agassiz have satisfactorily explained these deceptive appearances; so that we may now say with confidence that there is not the slightest evidence of such elevation, but much evidence to the contrary. Neither the mainland nor the keys are anywhere higher than may be accounted for by the action of waves, namely, from ten to fifteen feet, and it is inconceivable that this

elevation should have gone on progressively, preparing ground for the growth of successive reefs, without in the slightest degree affecting the contiguous and recently formed land. But this is precisely the mode of action of sedimentary deposit. Sediment cannot, of course, affect any thing but the sea bottom. It is to sedimentary deposit, therefore, that I attribute the gradual rising of the sea bottom from north toward the south, which, as we have seen, forms the necessary condition for the horizontal extension of coral reef through so great a distance.

Having thus shown that sedimentary deposit is almost absolutely necessary for the explanation of the southward extension of the reefs of Florida, let us attempt now to prove that such deposit has in fact taken place under the influence of the Gulf-Stream.

It is a well known law of currents bearing sediment, that, if from any cause their velocity is checked, they deposit a portion of their sediment upon the bottom; but if, on the contrary, their velocity is increased, they abrade their beds and banks. If, therefore, the velocity of a stream is greater on one side than on the other, abrasion will take place on the former and deposit on the latter. Now if such a stream bearing sediment make a sweep or curve, the velocity will always be greater on the outer and least on the inner side of the sweep. Hence there must necessarily be abrasion of the outer bank and deposit upon the inner. Thus in proportion as the outer curve extends by abrasion of the outer bank, the inner curve will extend also by deposit, and the tongue of land around which the sweep is made will grow longer and longer. If this tongue is cut away by artificial means, so as to convert this portion of the stream into a lake, around the outer margin of which sweeps the current, the still water within the sweep will become more and more shoal until it is again converted into a tongue of land. Now this is necessarily true under all circumstances. It makes no difference whether the stream runs between banks of solid matter or between banks of still water. If a stream bearing sediment run through still water, making a sweep or curve, the sediment must deposit principally upon the inner side of the curve, making shoal water at this part; the curve will extend and the shoal water will extend in the same proportion.

Now the Gulf-Stream is such a current. The strong sweep which it makes around the point of Florida is seen in Fig. 1. If, therefore, the Gulf-Stream bears any sediment, the conclusion seems irresistible

that the sweep of the curve has been increasing with the course of time, and that the tongue of land within the curve, namely, the peninsula of Florida, has been extending "*pari passu*" by means of sedimentary deposit. Or, even supposing that the position of the Gulf-Stream has always been the same as at present, and that Florida was once represented by a tongue of still water within the curve; this tongue of still water must have become more and more shoal by sedimentary deposit. I repeat, then, that upon any conceivable theory as to the position of the Gulf-Stream, whether its curve has been increasing or has been always the same as at present, if it carries any sediment, according to the law of currents, there must have been a progressive shoaling of water and making of land within the curve from north toward the south, and consequently a progressive formation of the conditions necessary for the growth of corals and their extension in the same direction. What evidence then have we that the Gulf-Stream does indeed carry sediment?

The Gulf-Stream is supposed to be a continuation of the great equatorial current which stretches across the Atlantic from the coast of Africa, strikes upon the wedge-shaped point of the eastern coast of South America, and divides into a northern and a southern branch. The northern branch uniting with the waters of the Amazon and Oronoco, runs along the coast of South America, through the Caribbean Sea, under the name of the Caribbean current, enters and receives strength in the Gulf of Mexico, from which emerging it sweeps round the point of Florida and along the coast of the United States on its way to the coast of Europe.

Now is it possible that a stream which washes so many shores, which runs through seas into which are poured such enormous quantities of sediment brought down by the largest rivers in the world, is it conceivable that such a stream should carry no sediment? On the contrary, it is well known that the sediment both of the Amazon and Oronoco rivers is carried by this stream and distinctly traceable for several hundred miles. Much of it is doubtless deposited along the coast and in the Caribbean Sea; but "according to Humboldt much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico."* Into the same gulf is also poured the enormous amount

* Lyell's Principles of Geology, p. 328.

of sediment brought down by the gulf rivers, especially by the Mississippi. Out of this gulf, the waters of which are thus highly charged with sediment, comes the Gulf-Stream on its way round the point of Florida. If then this stream mingles at all with the waters of the gulf rivers, it must necessarily carry sediment. That it does thus mingle is proved by the fact mentioned by Lyell,* that drift timber from the Mississippi is carried by this stream to the shores of Iceland and Europe. Now unless we suppose the whole of this sediment to be deposited in the gulf, it must reach, and, by the law of currents already insisted on, be deposited much of it upon the point of Florida. But we have the best reasons for believing that it is not all deposited in the gulf. The distance from the mouth of the Mississippi to the Tortugas is about five hundred miles. Taking the velocity of the Gulf-Stream through the Gulf of Mexico at three miles per hour, it would traverse this distance in about seven days. Now the finest sediment will not sink more than an inch in an hour; but supposing the mud brought down by the Mississippi sinks at the rate of one foot per hour, in seven days it would sink 168 feet. But the depth of the Gulf of Mexico and the Gulf-Stream is much greater than this. Therefore, fine sediment from the Mississippi would even reach the point of Florida, and what was not deposited there would be carried much farther on. We have farther evidence of this in the soundings made by the coast survey off the eastern coast of Florida, and the nature of the bottom which has thus been brought up. It can scarcely be doubted for a moment that the banks of sand and mud found in the bed and on the margin of the Gulf-Stream off the eastern coast of Florida were deposited there by that stream.

But it will be objected that the water of the Gulf-Stream is remarkable for its transparency. This objection, however, will entirely disappear when we consider the difference between rivers and ocean currents. The former are of slight depth and run over rough bottoms, and between banks possessing many inequalities of surface and offering, therefore, much resistance. Hence are generated partial currents upward and downward, to the right and left, which thoroughly

* Lyell's Principles of Geology, p. 721; and Proc. Amer. Ass. seventh meeting, p. 181, and eighth meeting, p. 140.

mix, as if by a sort of ebullition, the waters of the river. It is impossible that matters in suspension or solution should exist in one part and not in another, that is, that sediment should be carried by the deeper strata, while the superficial strata remain transparent. But with oceanic streams the case is quite different. Their great depth and the fact that they are bounded on all sides by still water, in other words, that they run over perfectly even beds and between perfectly smooth banks, cause them to flow without the slightest agitation, and without the ripples and inequalities which mark the currents of rivers. The currents of oceanic streams, therefore, do not in the slightest degree interfere with the natural subsidence of materials in suspension. They are equally as favorable to subsidence as perfectly still water. The surface transparency of the Gulf-Stream, therefore, forms no objection whatever to the supposition that it carries sediment in the deeper strata. Such sediment would necessarily sink beyond observation in the course of a few hundred miles.

After what I have already said, the bare inspection of the following figures will be sufficient to show the application of the theory in the formation of the peninsula.

Figs. 2, 3, & 4 are ideal sections through the middle of the peninsula, along the line *p p* Fig. 1, representing the different stages of the process, and showing how these two agents concurred in the formation of the peninsula. In all the figures *l l* is the sea level, *G S* the Gulf-Stream, *c*, *a''*, *a'*, *a*, sections of the lines *c d*, *a'' b''*, *a' b'*, *a b* of Fig. 1. In fig. 2, *c* represents the southern coast of Florida, at some time previous to the present elongation of the peninsula, that is, when it was in the present position of the northern shores of the everglades; *c n'' o''* the sea bottom at that time sloping into the Gulf-Stream, *G S*, *n''* the point where the depth of sixty feet is attained. At this point grew a reef (*a''*), leaving a ship channel *e* between itself and the southern coast (*c*). Fig. 3 represents the condition of things when by sedimentary deposit the sea bottom had become *a'' n' o'*, the reef (*a''*) had become a line of keys, the ship channel *e* had become shoal water dotted over with mangrove islands (not here represented), and another reef (*a'*) had formed at the limiting depth of sixty feet, and another ship channel *e'* between it and the previous reef. Fig. 4 represents the condition of things when the sea bottom had advanced to *a' n o*. Now *a''* the line of keys of

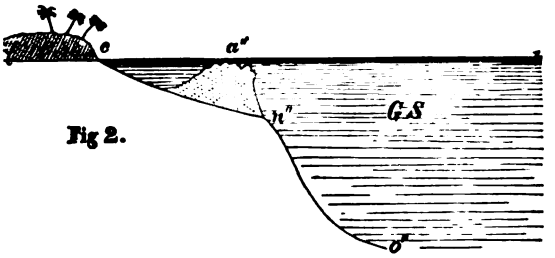


Fig 2.

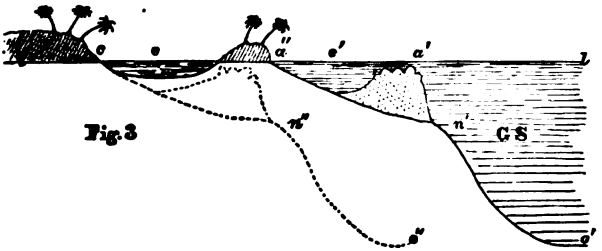


Fig. 3

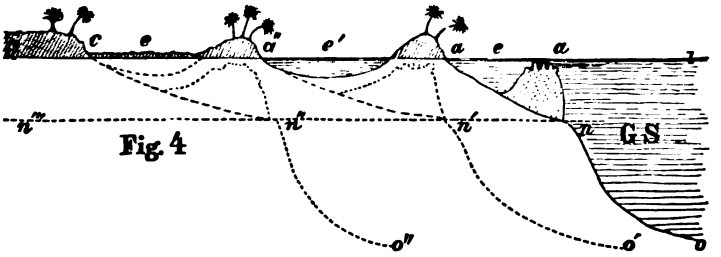
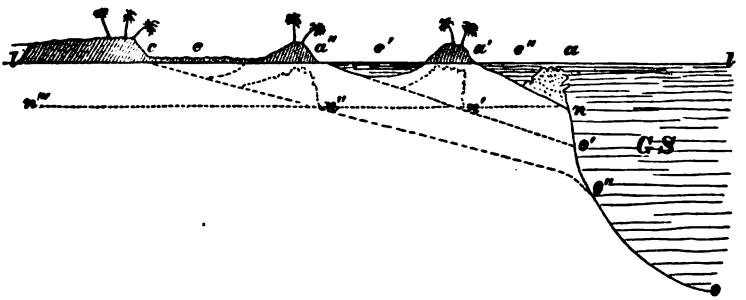


Fig. 4

the last figure has become the southern coast, and the shoal water *e* has become the everglades *a''*, the reef of the last figure has become a line of keys, and its ship channel *e'* shoal water, and at the limiting depth of sixty feet still another reef *a* with its ship channel *e''* has been formed. This figure, therefore, represents the present condition with the supposed former conditions in dotted outline.

It is evident that if this theory be correct, and no insuperable obstacle is interposed, the Gulf-Stream may continue to move its bed and the point of Florida to extend almost indefinitely. But such an obstacle is interposed in the island of Cuba. The Gulf-Stream cannot move much beyond its present position, nor Florida extend beyond the position of the present reef, except at the expense of Cuba and the Bahama Banks. Cuba can never be annexed by any natural agencies whether coral or current.

Or even supposing (as I have already done) that the position of the Gulf-Stream has always been the same as at present, and that the peninsula of Florida was originally represented by a tongue of still water; yet substantially the same changes would necessarily have occurred. Fig. 5 is an ideal section showing the succession of changes



upon this hypothesis. The letters represent the same things as on Figs. 2, 3, & 4. It is evident that as the point of Florida approached the Gulf-Stream the slope of the bottom would become steeper, and, therefore, the limiting depth would be attained at a shorter distance from shore, the consecutive reefs would be formed nearer and nearer to one another and the intervening ship channels would become narrower. Inspection of Fig. 1 shows that this is actually the case. We have chosen to trace this process only as far as the northern shore of the everglades, because thus far we have the most indisputable evidence of the recency of the formation. But in the same manner we might carry it still farther back in time and northward in space, and represent the successive reefs by which the superficial portions of the rest of the peninsula were formed. In Figs. 4 & 5 the space between $n\,n'\,n''\,n'''$ and $l\,l$,

equal to sixty feet, represents that portion of the peninsula which I have supposed to have been formed by coral agency alone.

There is one other fact of great importance and otherwise inexplicable which receives a ready explanation upon this theory, and which I think, therefore, is strongly confirmatory of its truth. I allude to the fact that the successive reefs are formed at some distance from one another; in other words, that the peninsula is formed by a succession of barrier reefs, instead of a continuous southward growth of fringing reef. The reefs of Florida are in some respects entirely peculiar. Barrier-reefs have heretofore been considered as always the result of subsidence of the sea bottom, and are invariably looked upon as the sign of such subsidence. But in Florida we have barrier-reefs where it is certain there has been no subsidence. We have here, therefore, a new form of barrier-reef. This important fact did not, I am sure, escape the attention of Professor Agassiz, for my own attention was first drawn to it by him; but I have seen no publication in which he has alluded to the fact, nor, as far as I know, has he ever attempted or even thought of a probable explanation. The explanation which I would offer is as follows: —

It is a well-known condition of coral growth that the sea water must be pure and transparent. Corals will not grow, therefore, on muddy shores or in water, upon the bottom of which sediment is depositing. Now it must be borne in mind that while the Gulf-Stream bears sediment in its deeper strata it is superficially transparent, and we have already shown that this must of necessity be the case with ocean streams. Suppose, then, that the matters held in suspension by the waters of the Gulf of Mexico, be of such a degree of fineness that it sinks to the depth of sixty feet by the time it reaches the point of Florida. It is evident that the sea bottom within the curve cannot rise by deposit above this level; for all the sediment is below. A stream bearing sediment in all its strata from bottom to top, such as a river for instance, will make land within the curve, but an ocean stream will only make shoal water within the curve. In the case supposed, where the bottom of the shoal water rises to within sixty feet of the surface, it will cease to secure deposit, and the water will remain perfectly transparent. Here, then, it would seem, we have the conditions necessary for coral growth. It must be recollected, however, that upon a sloping

shore with mud bottom, such as we have supposed always existed at the point of Florida, a fringing reef cannot possibly form, for the water is rendered turbid by the chafing of waves against the mud bottom; but at some distance from shore, that is, where the depth of sixty or seventy feet is attained and where the bottom is unaffected by the waves therefore, the conditions favorable for coral growth would be formed. Here would be formed a barrier-reef, limited on the one side by the muddiness and on the other by the depth of the water.

I have said that a stream running through still water and making a curve would deposit most of its sediment on the inner side of the curve. This is certainly true, but it is a more general expression of the truth to say that a stream running through still water will deposit sediment on both sides just where it comes in contact with the still water and is retarded by it. It would do so for the same reason that rivers which habitually overflow their banks form natural levees on either side, where the rapid current of the river comes in contact with the comparatively still water of the river swamp. It is well known that the natural levees of the Mississippi continue out to sea in the form of submarine banks, evidently formed by the checking of the velocity of the current on either side by contact with the still water of the Gulf. If the current is straight the deposit on both sides will be equal, and thus the stream will form banks for itself. If the stream is curved the deposit will be mostly on the inner side of the curve, as already said. Is it not probable that the Bahama Banks or, at least, that portion of them which lies to the east of Florida may have been formed to a great extent in the same way; that, while the peninsula of Florida has been made on one side, the Bahama Banks have been made on the other. It will be observed that the great Bahama Banks lie off the eastern coast of Florida, and that the Gulf-Stream runs in a narrow channel between them. At the point of Florida the deposit would, of course, be on the inner side of the curve and would go, therefore, mostly or entirely to the extension of that peninsula; but after the stream turns northward and becomes nearly straight, the deposit would be also on the other side, and thus probably have originated these banks. Or, even if we suppose that there originally existed in this position islands or submarine hills which turned the stream around the point of Florida, these have, doubtless, become greatly modified and extended by

sedimentary deposit. Probably, also, even the general form of the Atlantic bottom, very sloping until the Gulf Stream is reached, and then plunging rapidly into an almost unfathomable abyss, forming a deep bed for that stream, may, to some extent at least, be accounted for in a similar manner; for certain it is that a stream running through still water no less than one running over land will make its own bed, only in the latter case by abrasion it cuts out its own channel, while in the former by deposit it builds up its own banks.

This property of ocean streams, namely, that they form banks or ridges where they come in contact with still water, affords a possible and, as it seems to me, even a probable explanation of certain remarkable peculiarities of sea bottom brought to light by recent soundings across the Gulf-Stream.* Commencing from Charleston, the bed of the ocean slopes at first very gently, so that at the distance of fifty miles from shore it attains only the depth of twenty fathoms, and then very rapidly so that in twenty-five miles more it sinks to the depth of seven hundred fathoms or more. At the additional distance of another twenty-five miles, that is, one hundred miles from shore, at the depth of three hundred fathoms is found a ridge rising from unfathomable depth on one (coast) side, and one thousand five hundred feet above the hollow on the other side. At the distance of a little more than twenty miles more is found another ridge five hundred feet high, followed by still another hollow. Farther observations show that the Gulf-Stream is divided into longitudinal bands or streams of warm and cold water, and that the warm bands correspond to the hollows, and the cold bands to the ridges.

Now these ridges and hollows may be conceived to have been formed in either of two ways, namely, by igneous or by current agency. As upon land, valleys are formed either by igneous or aqueous agency; that is, may be valleys of elevation or valleys of erosion; so also in the sea, ridges may be formed by igneous or current agency, that is, may be ridges of elevation or ridges of deposit. In either case there would be conformity between the direction of the ridges and the direction of the current; only, in the one case the current would conform to the ridges, and in the other, the ridges would conform to the current.

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* Proc. Amer. Ass. Cleveland meeting, p. 167; and Washington meeting, p. 140. Silliman's Journal, 2d Series, Vol. XXI. p. 34.

In order to account for these ridges by this current-theory, the only supposition which it is necessary to make, is, that there exist in the bed of the Gulf-Stream, somewhere to the southward of the Charleston section, that is, at the southern extremity of the ridges, two or more submarine peaks or mountains, possibly a spur of the Bahama chain. If two such peaks existed in this position, and rose so high as to part the lower strata of the Gulf-Stream, there would evidently be formed bands of comparatively still water to the northward, and as evidently there would be lines of deposit determined by the still water; and the necessary result would be the ridges discovered by the coast survey. We see the same thing on a small scale in river currents. Every obstacle which parts the current determines the position of a sand ridge on the lower side of the obstacle, and in the direction of the current. There is this remarkable difference, however, between river and ocean currents, — that while in the case of rivers, the parted current quickly closes again, and the resulting ridge is therefore very short, — in ocean currents, such as the Gulf-Stream, the space between the two parts would be quickly filled by the cold water of the ocean. The parted currents would have, therefore, no disposition to coalesce, but would continue as bands of warm gulf water separated by bands of cooler and stiller Atlantic water, and the resulting ridges would therefore continue for great distances. I know not whether there have been any observations to test the comparative velocity of the warm and cool bands, but it seems to me that, on any conceivable theory as to the formation of the ridges, the velocity of the cool bands would be less.

Now, although it may be impossible in the present condition of science, to determine with absolute certainty whether these ridges were formed *previous* to the existence of the Gulf-Stream, by igneous agency, or whether they have been formed since by the sediment carried by the stream itself; yet, when we recollect that all the other peculiarities of the Gulf-Stream and the contiguous sea bottom are mainly referable to sedimentary deposit; when we reflect how simple and natural is the only supposition required, and how easily it explains all the phenomena, particularly the cold bands, which seem inexplicable on any other theory, unless we suppose the existence of lateral currents, it seems to me that the weight of probability will strongly incline to sedimentary deposit as the cause also of these ridges. In fact, every thing about the Gulf-Stream seems to point to the conclusion that it has been

the architect of its own curves, its own banks, and its own configuration of sea bottom.

There is one other conclusion which, though not connected with any particular theory of the formation of Florida, is nevertheless naturally suggested by the subject of this paper. We have seen that the peninsula of Florida has been progressively advancing towards Cuba as a fixed point, and the Gulf-Stream has been becoming more and more narrow. If, therefore, as is probable, the quantity of water carried by the Gulf-Stream has remained constant, it follows that the velocity with which this stream emerges from the Straits of Florida, and therefore the distance to which it penetrates the still water of the Atlantic, has been progressively increasing. Now, unless there has been some very remarkable change in the direction of this current, it necessarily follows that its warming influence upon the European Continent has been also progressively increasing. Have we not here, if not a sufficient cause, at least one of the true causes of that great change which we know has taken place in the climate of Europe since the Glacial period?

Thus we see that the advancing point of Florida has been progressively warming the climate of Europe, and thus, perhaps, controlling the destinies of the human race. Can we conceive a more beautiful instance than this of that sympathy which exists between the most distant portions of our globe, and which binds all its members together into one organic whole?

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10. Observations on the Orography of the Western portion of the United States. With a Map (not published). By William P. Blake, Washington, D. C.

The vast territory lying between the Mississippi and the Pacific was, but a few years since, an almost unknown region. Solitary explorers had here and there traversed the wilderness and brought home thread-like lines of topography to lay down across the great spaces marked *unexplored* upon our maps; but wide and unknown blanks still

remained. The explorations of Lewis and Clarke, of Long, Nicollet, and Fremont gave us the first glimpses of the true structure of the country along their several lines of travel. Fremont brought us to a knowledge of that singular feature in the physical geography of America, — the Great Basin, with its included Great Salt Lake, — and gave us the first reliable knowledge of the structure of the great Sierra Nevada of California and the extended valleys at its western base. But the unknown regions were so vast that these grand contributions to geography gave us, as I have observed, mere lines upon the map, and great spaces remained blank and unknown. The materials were, however, sufficient to authorize extensive generalizations, which map publishers and others rapidly made, not always distinguishing between the known and the hypothetical. The result was, that our maps left us little to desire, all the spaces were filled, and few could distinguish between the true and the fanciful. Thus those persons who have formed a conception of the orography of the great region west of the Mississippi from the ordinary maps have not attained a true idea of its surface or configuration.

The recently completed surveys, made to determine the most practicable railroad route to the Pacific Ocean, have made great additions to our previous knowledge. Indeed, it is believed that such extensive contributions to the geography and natural history of the interior of any country have never before been made in a similar space of time. Eight expeditions were sent out, each having an independent outfit, instructions, and line to survey. They crossed the country near different parallels of latitude, and their routes were selected with reference to the unexplored spaces. In many cases these parties, when in the field, were subdivided, and thus wider or parallel belts were explored. The combined results of these surveys, when plotted on the map of the Territories, fill up nearly all the previously blank spaces, and serve to connect together the results of explorations previously made. The position, direction, and altitude of ranges of mountains not before described have been made known. The direction and position on the map of a part of the Great Colorado and other rivers have been changed; and the boundaries of the Great Basin have been restored to the limits originally assigned by Fremont. The attention of the surveys having been specially directed to the determination of altitudes and grades, and a large number of accurate instruments having been

provided for this purpose, the results have an unusual interest in an orographic point of view. The altitudes of a great number of mountain passes in all of the principal ranges of mountains from the northern boundary line to Mexico have been very accurately determined, and the inclination of the slopes on each side made known. The materials which had been collected at the date of publication of the preliminary reports * were sufficient to permit of the construction of five profiles of the country from the Mississippi to the Pacific. These were reduced to one scale and published on one sheet under the direction of the Secretary of War. With such an accumulation of new material it is not surprising that previously constructed maps, and even the large map published from the Bureau of Topographical Engineers in 1850, which contained much that had not the authority of actual observation, should be found greatly in error.

It is from these new materials, together with the results of previous explorations, that I have prepared the map which is before us, on which I have laid down the principal mountains in black lines. I have attempted to present the trends of the principal ranges as accurately as possible, and to avoid the errors which result from drawing continuous lines of mountains along the water-shed, or divides between streams without regard to the structure or magnitude of different portions of the chain.

The great number and wide distribution of the mountains, and the variety of names under which the same chain is known at different places, make it necessary to consider them in groups, in order to facilitate descriptions and comparisons. We may readily form them into groups by taking advantage of the great geographical features, and indeed, they are already separated by Nature into three great divisions, which may be described in general as follows.

The first group consists of the great line of water-shed between the Pacific and the Atlantic Oceans, commonly known in part as the Rocky Mountains, and extending from the table-land of Mexico to, and beyond the northern boundary.

The second may include the Sierra Nevada of California and its prolongations south into Lower California and north into Oregon and

* Report of Hon. Jefferson Davis, Secretary of War, on the several Pacific Railroad Explorations. *House Doc.* 129. Washington, 1855.

Washington Territories, also all the ranges between this chain and the coast — the Coast Mountains of California.

The third group comprises the numerous and broken ranges lying between the first and second groups; the ranges of the Great Basin and Salt Lake, and along the Gila.

The first group is sufficiently characterized and separated from the rest by being the dividing ridge or crest of the continent from which the waters flow each way into the Pacific and Atlantic. The second is characterized by its lofty and unbroken line of snowy peaks forming a great wall along the Pacific. The third is well separated from the first, by the valleys of the Colorado and Green Rivers on the south, and Snake River on the north; while on the west, it is separated from the second group by the well-defined line of snowy heights of the Sierra Nevada, and further south by the low valley of the Colorado Desert and the Gulf of California.

It will thus be seen that these divisions of the mountains are founded upon geographical distinctions and not on the geological ages or relations of the chains, although it is believed that the same divisions will be convenient for geological descriptions. Two other groups may be formed of the long line of azoic rocks extending north-west from the Great Lakes, and of the Appalachian chain and its extension north through New England and Canada, and thus all the principal chains of the continent will be included.

I now proceed to a description of the leading features of each group.

We find the northern portion of the first group to be comprised of three principal and nearly parallel ranges, — the Rocky Mountains proper, the Bitter Root Mountains, and the Cour d' Alene Mountains. The last two ranges are intersected by the head waters of the Columbia River, but they are very properly referred to this group. The Bitter Root range extends from about latitude 46° to Clark's fork of the Columbia, and is prolonged beyond it to the eastern side of Flat Bow Lake, where it is known by another name; a parallel chain, or possibly a portion of the same, is there called Kootanie Mountains. The Bitter Root range is considered to be more lofty and rugged than the Rocky Mountains, with which it is joined by the dividing ridges between the Bitter Root River and the Jefferson fork of the Missouri. The Salmon River Mountains, further south, may be regarded as connected with these ranges. The Rocky Mountains proper extend, in

our territories, from the boundary in a direction south 20° east, 260 miles, to lat. 46°, where they curve to the south-west, and unite with the Bitter Root range. From this point south, there is but one range, of which however very little is now known, until it unites with the Wind River Mountains, which extend south 40° east for about 170 miles to the depression known as the South Pass. In this range we have the highest point of the group — Fremont's Peak, 13,570 feet in altitude.

From the southern end of this range to the next, there is a wide interval without any mountains. The country is a table-land or gently rolling prairie, but has an elevation of about 7,500 feet. We find on most of the maps published up to this time the representation of a range of mountains east of the South Pass, and extending from the vicinity of Fort Laramie to Fort Union on the Missouri. Recent explorations made by Lieut. G. K. Warren, U. S. Topographical Engineers, show that there is no range of mountains there; the country is a table-land or plateau.

About 140 miles south-east of the extremity of the Wind River range, we find the mountains again extending in parallel ridges towards the south, and inclosing wide rectangular valleys known as the Parks.

The first or Medicine Bow range is nearly coincident in its direction with the Wind River Mountains, and it is separated from a parallel range south-west of it by the head waters of the Platte River. These mountains, south of the Medicine Bow range, as represented upon the maps, display a singular rectangular intersection of the ridges, which is, however, believed to be in great part caused by drawing lines of mountains along the divides. It is most probable that the ridges are nearly parallel, and I have attempted to show what is probably their true structure on the map. These mountains are generally known as the Park Mountains, and extend on the south to the sources of the Arkansas River. Their general direction is north and south, and some of the highest peaks of the group are found there.

South of these Park ranges we find the broken and composite character of the chain still preserved. The ranges are numerous, and known by different names. They inclose long valleys, through which the Rio Grande flows, occasionally breaking across the low points of the ranges, and thus entering several valleys in succession. On the east of the stream we find the Santa Fé, Sandia, Manzana, Organ, and

Hueco ranges; and on the west the San Juan, Chusca, and Sierra Madre. The Sierra Madre diverges from the Rio Grande, a few miles south of the parallel of 34°, and trends about north 20° west until it disappears in the table-lands near the parallel of 36°. The Organ Mountains, on the other side of the river, appear to be more northerly in direction, trending north 14° west. This is about the trend of the Sierra San Juan and the Hueco range. The Santa Fé range and the mountains north as far as the Sangre de Cristo Pass appear to be nearly north and south in their trend. The only range with a north-east trend is found east of the Hueco range, and west of the Pecos River, and is known as the Guadalupe. It trends north 38° east, and may be regarded as a part of the line of north-east and south-west elevations which are found through Texas and Arkansas.

We have thus followed the great chain of mountains forming this group from the British possessions on the north to the Mexican boundary on the south. The length of this great chain, or rather the distance over which it extends in the territory of the United States, is about 1,400 miles. Its general direction may be said to be north-north-west and south-south-east; but, as we have seen, there are several local but decided deflections. The most prominent is that of which the Wind River range forms a part, where the direction becomes about north 55° west. The trend of the Santa Fé range and the Organ range is nearly north and south, while the Bitter Root and Rocky Mountain range proper trend about north 25° west. A well-defined parallelism of ranges is preserved throughout this group, being distinct along the Rio Grande, south of the Park ranges. Here, there are three or more parallel ranges inclosing long valleys.

We can, as yet, form only an approximate estimate of the general elevation of the whole or principal chain, although our knowledge of the height of the passes has been greatly increased. The principal measurements which have been made are presented in the following table.

TABLE OF PASSES.

Pass.	Range.	Altitude.	Authority.
Marias Pass.	Rocky Mountains.	7,600	Stevens.
Lewis and Clarke's.	" "	6,323	"
Cadottes.	" "	6,044	"
Hell Gate.	" "	6,000	"
——— (Kooskooskia River).	Bitter Root.	7,040	"
South Pass.	Wind River.	7,490	Fremont.
Bridgers.		7,500	Stansbury.
Cheyenne.	Black Hills.		"
(Nameless)	Park Mountains between New and Old Parks.	9,000	Fremont.
(Nameless)	Park Mountains between Old and South Parks.	11,200	"
Cochetopa.	San Juan.	10,032	Gunnison.
Sangre de Cristo.		9,396	"
Raton.	Raton.	7,479	
Albuquerque (San Antonio).	Sandia.	6,937	Whipple.
Campbell's.	Sierra Madre.	7,750	"
Camino del Obispo.	" "	7,946	"
El Paso del Norte.	Organ Mountains.	3,830	Parke.
Hueco.	Hueco.	4,811	Pope.
Guadalupe.	Guadalupe.	5,717	"

We see from this table that the altitude of the passes decreases, both towards the north and the south, the greatest height being found in the Park ranges near the parallel of 40°, or at the sources of the south fork of the Platte River.

SECOND GROUP.

The mountains of the second group, at the extreme north near the boundary, are as yet but little known to explorers. It is, however, certain that the extended range of the Cascades has a nearly north and south trend, and is continuous, — broken, of course, by passes and a deep gorge at the Columbia, — from the British Provinces to the California line. This range, throughout its extent, is characterized by a line of lofty volcanic cones, their summits being covered with perpetual snow. The lava which has flowed from them has extended far from their bases, and has covered the greater part of the rocks of the range from view. It is most convenient to regard the Cascade range as terminating at the south at the Klamath River, near the boundary between California and Oregon. The peak of Shasty might, however,

be very properly regarded as a part of the range, it being the last of the series of volcanic cones. This mountain rises north of Pitt River, and is in this way partly isolated from the Sierra Nevada. Its elevation is now estimated to be not less than 20,000 feet.

We do not find the great snowy range, or the Sierra Nevada to be composed of one continuous elevated ridge, forming a sharp snowy crest, as is generally supposed. It is formed of many and nearly parallel ranges which inclose elevated valleys, precisely as in the Great Basin. The northern part of the Sierra is flattened down into broad table-lands or a plateau, hemmed in on both sides by ranges. The plateau in the vicinity of the Madelin Pass is about twenty miles broad, and has average elevation of about 5,000 feet, the ranges on each side rising from 500 to 3,000 feet higher. The plateau is irregular and broken by short ranges, but extends northward into Oregon to Lake Abert, and the numerous small lakes in its vicinity. These lakes, in fact, occupy the lowest portion of the plateau, and a chain of them is formed along the whole crest of the Sierra to its southern end. This constitutes a peculiar and interesting feature of these mountains, and shows the great amount of precipitation on their summits.

The passes through these mountains generally follow the plateaux, and either turn the points of the isolated ridges, or cross them at their lowest point. We find, in passing southward along the crest, that the elevation of these plains increases. This is shown by the observations of those who have searched for locations for a wagon road. Thus, Carson's Pass, and that traversed by Fremont in 1844, are nearly 8,000 feet high, and one, from Sonora to Walker's River is 10,083 feet.

Still further south, the chain commences a deflection to the west, and here, the altitude decreases. The peculiar broken character is, however, preserved, and we find high valleys beautifully wooded with oaks and covered with grass. Here the passes vary from 5,300 feet to 4,000 feet in elevation, the plains being about 8,500 feet. The width of the rocky outcrops is also reduced at the Tejon, to about thirteen miles, and the ridges do not attain an elevation of over 7,000 feet. It here unites with the transverse chain, the Bernardino Sierra, and this may be considered its southern extremity, its northern being at the end of the Cascade range. It thus extends over a distance of about five hundred and seventy miles, and has the average trend N.

27° W. Its northern portion is nearly north and south; its central N. 30° to 35° W.; and its southern end has a remarkable bend to the south-west. We here have a north-east trend, almost the only example west of the Guadalupe Mountains.

The next range, the Bernardino Sierra, or the southern extension of the Sierra Nevada, has an entirely different direction, and makes a sudden and remarkable deflection to the south-east. Indeed, its trend is N. 76° W., nearly transverse to the Sierra Nevada. It is nearly parallel with the adjoining coast, having, in fact, determined its trend, and extends from the vicinity of Point Conception, eastwardly to the high peak of San Bernardino. It forms part of the southern boundary of the Great Basin, and has an average elevation of about 6,000 feet, its highest peak, San Bernardino, being probably over 8,000 feet in height.

Passing still further south in our descriptions, we find the chain again changing its direction at the San Bernardino, or San Gorgoño Pass. From this point southward, high ridges extend uninterruptedly to and beyond the boundary line, and indeed are found throughout the whole length of the California Peninsula. I have described these mountains under the name of Peninsula Sierra. The northern portion of the chain, within the limits of the State of California, appears to trend nearly north and south, (to the observer who stands in the valley of San Bernardino,) but in reality, it deflects westward, and the main direction may be considered N. 23° W., to N. 30° W. for the whole length. The peak of San Gorgoño, the highest peak north of the boundary, is probably 7,500 feet in elevation.

The Coast Mountains of California are included in this group. They consist of many parallel ranges inclosing large and fertile valleys, and thus form a broad belt of mountains along the coast. The ranges south of the Golden Gate are known under many local names; as, for example, San Bruno range, Santa Cruz range, Gabilan range, and Sierra Santa Lucia. The topography of that region is not yet accurately known, and definite and detailed descriptions cannot now be given. It is probable that these ranges do not average over 3,000 or 4,000 feet in elevation. Monte Diablo, the highest peak, near San Francisco, is about 4,000 feet high. North of the Golden Gate, the mountains are higher, and occupy a greater area from east to west. The general trend of the ranges is north-westerly.

We are yet without sufficient data to enable us to form a just estimate of the average elevation of the great chain which forms the second group, but the height of many of the passes is given in the annexed table.

TABLE OF PASSES IN THE CALIFORNIAN CHAIN.

Pass.	Range.	Altitude.	Authority.
Yakima.	Cascade.	3,467	Stevens.
Naches.	"	5,000	"
Snoqualme.	"	3,500	"
Columbia River.	"		
Madelin.	Sierra Nevada.	5,667	Beckwith.
Nobles.	" "	6,346	"
Johnsons.	" "	6,752	Goddard.
Daggetts.	" "	6,824	"
Carson (Fremonts ?).	" "	7,972	"
West.	" "	9,036	"
Walker's River to Sonora,	" "	10,133	"
Walkers.	" "	5,300	Williamson.
Tahechaypah.	" "	4,000	"
Humpahyamup.	" "	5,351	"
Tejon.	" "	5,364	"
Cañada de las Uvas.	" "	4,256	"
Williamsons.	Bernardino.	3,164	"
San Francisquito.	"	3,440	"
Cajon.	"	4,676	"
San Bernardino or San Gorgoño.	Peninsula.	2,808	"
Warners.	"	3,780	"

THIRD GROUP.

The mountains which are classed in the third group do not form one long and continuous chain, as in the first and second. The ranges are exceedingly numerous, and are ranged in parallel lines with a general north and south direction over a broad area. As a group, they are most readily considered in their succession from east to west rather than from north to south.

Along and near the parallel of 41° the most prominent or principal range is known as the Wahsatch Mountains. These mountains rise on the eastern side of the Great Salt Lake, and extend towards the south, forming the eastern rim of the Great Basin. Between this range and the Sierra Nevada, there is a constant succession of ridges, which are short and much broken, but are arranged in parallel lines, and gener-

ally trend north and south. Their altitude varies from 1,500 to 3,000 feet above the general surface of the basin. This general surface or succession of slopes and valleys between the ranges, along the parallel of 41°, has an average elevation of 4,500 feet. There is one great swell of the surface about midway between the lake and the Sierra, which is produced by the Humboldt Mountains, the principal range of the basin. It reaches an altitude of nine or ten thousand feet, or two to three thousand feet above the plain, and the summit of the principal pass through it is 6,579 feet above the sea. The range, so far as known, extends from the Snake River on the north to the parallel of 40°, but is probably continued farther south, and is nearly in a line with the Pai-Ute range separating the Colorado from the Great Basin farther south.

On a line westward from Santa Fé or Albuquerque, near the parallel of 35°, we also find in succession, the Mogoyon, Aztec, Aquarius, Cerbat, Ak-mok-ha-bi, and the Pai-Ute ranges. They are all nearly parallel, and have a north-westerly trend. The Mogoyon range exhibits the greatest departure from parallelism, apparently trending in its southern portion towards the east and uniting with the ranges of the first group, along the Rio Grande. The Aztec range appears to be continuous southward, from near the Colorado, to and beyond the Gila to the Mexican line. The Aquarius and Cerbat ranges also appear to commence near the Colorado, and extend to the Gila. The Pai-Ute range is composed of many minor ridges, which form a part of the wall of separation between the Great Basin and the Colorado. This range is connected with the short isolated ridges and ranges of the Great Basin. Still west of the Pai-Ute Mountains, there is a succession of mountain ridges forming a range bordering the Colorado Desert on the east. It appears to trend south-easterly across the Colorado and Gila near their confluence.

It is most probable that all these ranges are connected with, or are in the line of prolongation of, the principal ranges at the north already noticed. Thus, the Humboldt Mountains probably find their southern continuation in the Pai-Ute range, and the Wahsatch in the Mogoyon. It is, however, possible that the southern end of the Wahsatch range trends towards the west, conforming to the curvature of the Colorado, and similarly to the southern end of the Sierra Nevada.

This general notice of the ranges includes only the most prominent

or well-known lines of elevation. An idea of their relations and general direction will be best obtained by reference to the map.

TABLE SHOWING THE ELEVATION AND POSITION OF THE PRINCIPAL PASSES IN THE RANGES OF THE THIRD GROUP.

Pass.	Range.	Elevation.	Authority.
	Pah-o-tom Mountains, (First range west of Salt Lake).	6,364	Beckwith.
	Granite Mountains.	4,666	"
	Pi-ja-ro-ja-bi.	5,076	"
Goshoot.	Goshoot.	6,992	"
	Wa-ro-ja.	6,726	"
Humboldt.	Humboldt.	6,579	"
Agate.	Quartz Mountains.	5,441	"
	Pond Mountains.	4,648	"
	West Humboldt.	4,141	"
	Cold Spring.	5,473	"
Passes around the Mud Lakes.	Black Rock Ranges.	4,079 to 5,473	"
Uintah.	Uintah.	8,373	Gunnison.
Wahsatch Gap.	Wahsatch.	7,820	"
Ahmokhabi.	Pai-Ute.	5,262	Whipple.
San Francisco.	Mogoyon.	7,472	"
Aztec.	Aztec.	6,281	"
El Dado.		5,183	"

Having now described the prominent orographic features of each group, and shown that the first and the second include great chains which are geographically distinct, I propose distinctive names for them by which they may be conveniently known in descriptions, and which will not conflict with the names now applied to any portions of them.

For the first group, it may be said that the name Rocky Mountains is already well known and sufficient for the whole chain which I have described. But this is a local name, and pertains to a small portion only of the great chain, — a portion north of the parallel of 46°. The ranges further south were known by other names long before the name *Rocky Mountains* came into use; and being then within the limits of Mexico, received Spanish names, by which they are now known. Moreover, the great chain extends down into Mexico, and north to the Arctic Sea or from one end of the continent to the other. As it may be said to commence in the south, where it forms nearly the whole

of the great table-land of Mexico, or *Anahuac*, I propose to call it the *Anahuachian Chain.*

For the second great chain which traverses the two Californias, it is thought that a more appropriate name than *Californian Chain* cannot be found. It might with great propriety be called the *Aurian Chain* or *Columbian Chain*, both of these names having been considered, but relinquished in favor of the former, the only objection to which, that occurs to me, being the danger of regarding the chain as confined to the limits of the Californias, while the name is intended to include the Cascade ranges and their northern prolongations.

For the mountains of the third group, I suggest the use of the general appellation *Aztecian Chains* or *Great Basin Chains*, until further explorations shall show us their relations with more detail, and permit more definite divisions to be made.

These names harmonize with the elegant general title proposed for the Alleghanies and their extensions by the Messrs. Rogers; a name which has now passed into general use, and the utility of which is abundantly proved.

The two great chains are each about 1,500 miles in length, within the territory of the United States, but the Californian chain extends along the peninsula 800 miles further south, and the Anahuachian becomes the table-land of Mexico. We find that the greatest breadth of surface covered by the chains is along the parallel of 40° from long. 105° 30′ to 124°, or about 1,200 miles. This, however, includes the elevated table-land at the sources of the Colorado. It will be seen by the map that the breadth decreases towards the north and the south.

In comparing these great chains together, we are at first struck by the general and close parallelism which they exhibit throughout. Even the inequalities or deflections in the course of one chain find their counterpart in the others; as, for example, the east and west trend in the Californian chain at the Bernardino Sierra finds a parallelism in the deflection of the Anahuachian chain, of which the Wind River Mountains are a part. So, also, the peculiar south-western bend of the southern end of the Sierra Nevada, has, to all appearance, a counterpart in the deflection of the southern end of the Wahsatch Mountains along the Colorado River.

These great deflections from the general course of the chains, and especially the great and sudden bends to the west, are peculiar and

interesting features, and are rendered more so by their parallelism, and the probability that they result from the same cause.

The parallelism of the coast line with the mountains is also interesting from its close conformity, showing that, in general, the shores are rocky, the coast line being principally formed by erosion and not by deposition, as may be said of our Atlantic seaboard. We may, also, infer the existence of strong coast currents, which carry away the loose debris of the rocks beaten down and ground together by the waves.

It is an interesting fact, that the most open and lowest passes in the chains, in other words, the greatest and most decided breaks are formed at the angles or points where the greatest deflections or bending of the chains commence. The South Pass between the Wind River and the Medicine Bow Mountains, and the Pass of San Gorgoño or San Bernardino, and the low passes of the Tejon and Cañada de las Uvas are examples.

One of the most important characteristics presented by the mountains is the number of ridges or ranges which unitedly form the great chains. This is best seen in the mountains of the Great Basin and in the Californian chain, although it is strikingly evident in the Anahuachian chain. These ridges are not ranged side by side, but a general and prevailing overlapping position may be observed. Thus each range in succession is found to extend beyond the other. This overlapping character, or distribution *en echelon*, is not a new feature in the composition of mountain chains, but is found in the Appalachians, and is one of the results of the earth's contraction, which according to the theory advanced by several geologists, and ably sustained in this country by Prof. Dana, is the cause of the great plications of the crust. The overlapping is very clearly shown in the Coast Mountains of California, where the ranges reach the coast successively from the south northward. The Bay of Monterey is included between the end of the projection of one ridge into the ocean at Point Pinos, and the side of another which ends much farther north. The same character is seen in the mountains along the Gila River, in the Great Basin, and at many other places. It will be observed that this character is not confined to the minor ridges or ranges, it extends to some of the important ranges, they being found to sustain a similar relation to each other.

This parallelism and overlapping of the ridges reveals to us the fact, that the rocks of that region are folded and crumpled together as in

the Appalachians, and that similar forces have been exerted on them upon a much more grand scale. Instead of one chain we have several, each rivalling the Alleghanies in extent and altitude. The phenomena of plication are not only indicated by the topography, but have been observed in the Sierra Nevada and Coast Mountains of the Californian chain. They are, also, found in the chains of the Great Basin.

We cannot contemplate the peculiar relations of the principal chains, as exhibited on the map, without recognizing the result of the action of two opposing forces.

If we conceive the principal lines of flexure to be meridional, north and south, the folding may be referred to a force or contraction acting in east and west lines, and this may be termed the equatorial contraction. The trends of the ranges show, also, the action of force in another direction; or from north to south, a polar contraction, to which the sudden bends in the long chains of mountains may be referred.

These bends have already been noticed, but may again be enumerated. They are found in the Sierra Nevada, east of the Bay of San Francisco, in its southern portion, where it curves gradually round to the south-west; and in the Bernardino Sierra trending at nearly right angles to the Sierra Nevada. Parallel deflections are found in the Anahuachian chain in the Wind River range, and again they are seen in the Washatch range of the Great Basin chains. Thus all the long chains are bent as if by compression upon the ends, and the action of force exerted at right angles to the force which has produced the prevailing meridional folding is clearly indicated. It is most probable that this force has acted in north and south lines, and we may term it the *Polar* force or contraction. The overlapping of the ridges and ranges is another evidence of this polar contraction. We may, also, refer the great north-west and north-east trends to the interference of this polar force or resistance with the equatorial contraction, the diagonal trends being the resultants of the two forces. This train of thought leads to interesting speculations concerning the gradual cooling and contraction of the crust of the earth, but it is not my intention to follow out the subject at this time.

I have thus endeavored to present a connected view of the principal mountain chains, and some of the conclusions which we may draw from a study of their relations now that we have the principal chains placed with approximate correctness on our maps. We may, also, conclude

that there is not a region where the great dynamics of the earth are recorded on a scale of greater simplicity and grandeur than in our own land between the Mississippi and the Pacific.

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11. General Description of the Country adjacent to the Boundary between the United States and Mexico. By Col. W. H. Emory.

The boundary between the United States and Mexico extends entirely across the continent from ocean to ocean. That portion of it which is formed by the Rio Bravo, below the mouth of the San Pedro or Devil's River of Texas, makes a boundary which, in the absence of extradition laws, must always be a source of controversy between the United States and Mexico.

In other respects the boundary is a good one; and if the United States is determined to resist what appears to me the inevitable expansive force of her institutions and people, and set limits to her territory before reaching the Isthmus of Darien, no line traversing the continent could probably be found which is better suited to the purpose.

In this respect it is fortunate that two nations which differ so much in laws, religion, customs, and physical wants, should be separated by lines marking great features in physical geography. The boundary is embraced in the zone separating the tropical from the temperate and more northern regions. Here waters unite, some of which are furnished by the melting of northern snows, whilst those from the south are supplied from mountains watered by the tropical rains. To the north of this zone the showers of the tropics cease to refresh the earth; and within it all the flora and fauna which characterize the northern and temperate regions almost disappear, and are not entirely supplanted by those of the tropics. It is, indeed, a neutral region, having peculiar characteristics, so different as to stamp upon vegetable and animal life features of its own.

The most remarkable and apparent difference between this region and those of the States of the Union generally, and that which perhaps

creates as much as any other one cause the difference in its botanical and zoölogical productions, is the hygrometric state of the atmosphere. For while the plants and animals assume new forms in life, the crust of the earth, the soil, and the rocks, are everywhere familiar and have many types, indeed fac-similes, over the rest of the American continent. It is very arid, but this is, also, the character of all the country north of the tropics, and west of the 100° meridian of longitude, until you reach the last slope to the Pacific, a narrow belt seldom exceeding two hundred miles in width, and sometimes not more than ten. The zone extending from the Gulf of Mexico to the Pacific, embracing the boundary, contains a large proportion of arid lands, yet this dry region is, perhaps, narrower on the line of the boundary than on any portion of the continent north of it within the limits of the United States, and is occasionally refreshed by showers in the summer season, and so far presents an advantage over the arid belt to the north.

A general description of the topographical features of the country along the boundary between the United States and Mexico (traversing the whole breadth of the continent) cannot be made comprehensive without presenting in the same view the great outline of the continent itself.

It is well known, the most extensive feature in the continent is the plateau, or table-land, which traverses this country from the unexplored region of the north, to its southernmost extremity, ranging in width from five miles to one thousand, attaining its greatest elevation in the Andes of South America; its least elevation and breadth on the Isthmus of Panama and in Central America, and its greatest breadth about the parallel of thirty-eight degrees north latitude. On the northern portion of the continent this plateau attains its greatest height in Mexico, where it is ten thousand feet above the level of the sea. Its lowest depression is along the line of boundary, about the parallel of thirty-two degrees north latitude, where it is about four thousand feet above the sea. Thence, it ascends again and preserves an elevation ranging from seven to eight thousand feet, to near the forty-ninth parallel, where it is again depressed. This plateau, both in North and South America, occupies the western side of the continent, and is traversed by ranges of mountains, the highest peak of which in North America is Mount Elias, seventeen thousand feet above the sea; and in South America is Mount Aconoagua, 21,500 feet above the sea. The climatic feature in this plateau, within the United States, is excessive

dryness, and great changes in temperature between day and night, often as much as sixty-five degrees of Fahrenheit.

The principal ranges of these mountains in North America, naming them in the order of their proximity to the coast of the Pacific Ocean, are first, the Cordilleras of California and Oregon, or the coast range of mountains; second, the Sierra Nevada (which, as its name denotes, is a ridge of mountains and craggy rocks covered with snow); third, the Sierra Madre, another range of mountains which were supposed to separate the water flowing into the two oceans; and fourth, the Rocky Mountains.

The idea conveyed by the name, Sierra Madre, is very generally adopted by the Mexicans, yet I doubt very much if any continuous ridge or chain of mountains can be found which separates the waters flowing into the Pacific from those flowing into the Atlantic. I am, also, quite well satisfied that the mountains known as Sierra Madre in New Mexico are not the same range as those known by that name in Chihuahua and Sonora, and that both are distinct from the range west and south of Monterey, of the same name; but the coast range, the Sierra Nevada and the Rocky Mountains, preserve a very considerable continuity throughout the limits of the United States. The coast range follows the generally north-west direction of the beach of the Pacific coast, and for a very considerable distance rises abruptly from the sea. Along the whole coast it is in view of the navigator, presenting an imposing and ever-changing panorama. It may be said to terminate at Cape San Lucas, the southern extremity of Lower California.

It is the slope towards the sea of this range of mountains, which forms the western border of the arid region, and is, in my opinion, the only continuous agricultural country west of the one hundredth meridian. There are many detached valleys and basins affording facilities for irrigation where the cereals, the vine and all the plants which conduce to the comfort of man, are produced luxuriantly; but they form the exception rather than the general rule, and are separated by arid plains or mountains.

The Sierra Nevada, the Cascade range, and the Rocky Mountain ranges, preserve a general parallelism to each other, and to that of the coast range; and, to use a military term, are mostly developed *en échelon*. Commencing at the north they can be traced continuously until we reach to within a few degrees of latitude of the region

of the boundary, where occurs in all except the coast range the remarkable depression in the continent, or rather absence in the continuity of the ranges of mountains hereafter to be described.

The Sierra Nevada, in latitude thirty-three degrees north, branches; one great division uniting with the coast range and forming the elevated promontory of Lower California, and presenting, when figured on the map, the appearance of the letter Y (Tulare valley resting in the fork of the letter); other branches or spurs are thrown off in a south-east direction, crossing the Gila at the mouth and many miles above, and traversing the newly acquired territory in the meridian of Santa Cruz and Tucson. That range, together with the Sierra Madre and the Rocky Mountains, about the parallel of thirty-two degrees, lose their continuous character, and assume what are graphically described in the western country as lost mountains, that is to say, mountains which have no apparent connection with each other. They preserve, however, their general direction, north-west and south-east, showing that the upheaving power which produced them was the same, but in diminished and irregular force. They rise abruptly from the plateau and disappear as suddenly, and by winding around the bases of these mountains it is possible to pass through the mountain system in this region, near the parallel of thirty-two degrees, almost on the level of the plateau. So that if the sea were to rise four thousand feet above its present level, the navigator could cross the continent near the thirty-second parallel of latitude. He would be in soundings of uniform depth from the Gulf of California to the Pecos River. He would see to the north and to the south prominent peaks and sierras, and at times his passage would be narrow and intricate. At El Paso he would be within gunshot of both shores.

Passing to the south of this parallel, in about that of thirty-one degrees, we find the plateau rising rapidly to the table-lands of Mexico; the ranges above described are no longer traceable, and the plateau gives evidence of having been disturbed by tremendous plutonic forces, and the mountains assume a loftier and more rugged and diversified appearance. As I have said before, the Sierra Madre range of mountains cannot be traced distinctly with our present information. The Rocky Mountains near the head-waters of the Rio Bravo throw off spurs which add to the confusion, and makes it difficult to separate this range from that called in New Mexico the Sierra Madre.

It may be a question whether the Rocky Mountain range is not divided by the Rio Bravo; and if so, that which I have designated as the Sierra Madre of New Mexico, will in that case become a spur of the Rocky Mountains. The geological formations to which I shall presently refer, seem to favor this hypothesis. If that hypothesis be true, the Sierra Madre of New Mexico and the Rocky Mountain system are the same, and are only divided by the Rio Bravo. But this is a question which does not affect the general topographical description of the country, and may be disregarded here. What I have described, refers more particularly to the country west of the Rio Bravo del Norte.

The Rocky Mountain system commencing in the north, beyond the source of this river, and beyond the limits of the 49th degree of north latitude, is the distinguishing feature of the country east of that river, until we reach the great plains lying between the base of those mountains and the valley of the Mississippi. The axis of maximum elevation preserves a general parallelism to the Sierra Nevada range. Its principal chain, after passing the 36th parallel of latitude, becomes less elevated, and finally terminates in the Organ Mountains, near El Paso, reappearing again to the south and east, and becoming at last merged with the great mountain masses in Mexico.

Another branch of these mountains diverges about the head of the Pecos, and running south, with unequal elevation, crosses the Rio Bravo, between the 102d and 106th meridian of longitude, forming the great bend in that river, and producing one of the most remarkable features on the face of the globe, — that of a river traversing at an oblique angle a chain of lofty mountains, and making through these, on a gigantic scale, what is called in Spanish America, a cañon; that is, a river hemmed in by vertical walls. These mountains, to the south of the river, expand in width and height, attaining a great elevation in the neighborhood of Monterey, Saltillo, and Buena Vista, and from one side of the Bolson de Mapimi; and it is my impression that these mountains are identical with what is there called, in Neuvo Leon, the Sierra Madre.

A third, but subordinate range, branches from the main chain, about the same parallel as that last described, and terminates in the Llano Estacado, or the Stake Plains, from which issues the Red River, and other rivers of Texas. From the foot of the Llano Estacado, the

country falls sometimes by steps, but most generally by gentle slopes, to the shores of the Gulf of Mexico; the crust only broken in a few places by the washing of streams, and by the protrusion of igneous rocks. This igneous protrusion, composed of greenstone or basalt, is traced from the San Saba Mountain, by the head of the Leona, to Santa Rosa in Mexico, where it unites with the main ridge at an angle of about forty-five degrees. The point where they unite is rich in silver mines. At Santa Rosa, the Spaniards had sunk extensive shafts, and made a tunnel a mile and a half in length, which was not then complete, when the revolution of 1825 broke out, and since then, all extensive operations have been suspended, and the country, rich in minerals and in the production of the cereals, and of the tropical plants, has been a prey to the incursions of banditti and Indians.

It has been observed that these metaliferous rocks generally occur at such places where two systems unite, or where some unusual disturbance or change in the geological structure takes place. Hence, we may expect to find these silver-bearing rocks along the boundary line, where the upheaving force after passing under the bed of the Gila River begins again to reappear to the south.

The remaining mountain feature of North America, the Alleghany, is referred to here only to illustrate by comparison, the mountain system of the western part of the continent. That chain, grand as it is, sinks into insignificance, when compared to those which I have attempted to describe. It is nearly at right angles to the western chain of mountains, is less elevated, and sheds its waters, as is well known, clear on both sides; on the one side into the Atlantic, and on the other into the Mississippi and the Gulf of Mexico. On both sides, the slopes are comparatively gentle, and the soil fertile, and, refreshed by frequent showers, yields in abundance all that contributes to the wants of man; and on the western side of this slope, between it and the desert border of the Rocky Mountains, such an expanse of fertile country exists, as can be found in one body nowhere else on the face of the globe, producing all the fruits of the earth, including those found in every zone, from the boreal regions to the tropics. Persons who are familiar with its character, as most who read this memoir will be, will scarcely be able to comprehend, still less to believe the character given to the more western and less favored regions described in this report. In the fanciful and exaggerated description given by many,

of the character of the western half of the continent, some have been, no doubt, influenced by a desire to favor particular routes of travel for the emigrants to follow; others, by a desire to commend themselves to the political favor of those interested in the settlement and sale of the lands; but much the greater portion, by estimating the soil alone, which is generally good, without giving due weight to the infrequency of rains, or the absence of the necessary humidity in the atmosphere to produce a profitable vegetation; but be the motive what it may, the influence has been equally unfortunate, by directing legislation, and the military occupation of the country, as if it were susceptible of continuous settlement from the peaks of the Alleghanies to the shores of the Pacific.

Between the two most distinctly marked ranges of mountains before described, the Rocky Mountains and the Sierra Nevada, a succession of minor ranges occur, some of which are many hundred miles in extent, while others appear like isolated mountains rising above the general level of the plateau. Most of them preserve a general system of parallelism; others present their lines of maximum elevation, forming very considerable angles with the general direction; and all, when traced upon a map, exhibit lines varying from right lines to every degree of curvature. The whole system, plateau and mountain, seems to have been produced by a succession of forces analogous to each other in direction, but differing in intensity and occurring at long intervals. The prevalence of granite and other unstratified rocks throughout the Sierra Nevada, suggest the probability of its being the oldest range of mountains. The identity of its rocks generally with those of the Alleghany Mountains, mark these two distinct and detached chains as probably contemporaneous. The rocks marking these mountains are the description commonly traversed by gold and copper mines, as is the case in Oregon, California, Virginia, and North Carolina.

Travelling eastward from the Pacific along the bed of the Gila, we encountered similar rocks in a chain of mountains as far east as the Pimo Village. This chain, characterized also by the presence of gneiss, mica, and talcose slate, has been traced as far south as the present boundary, where it crosses the Santa Cruz River, between longitude 110° and 111°; and in that neighborhood we saw everywhere the remains of gold mines, from which the operators had been driven by the Apaches.

Pursuing our course eastward, along the boundary, from the meridian of 111°, we cross the San Pedro, the Guadalupe, and the San Luis range of mountains, in the order in which they are named, the middle range being chiefly characterized by sienitic aggregates, granitic lava, and immense masses of conglomerate or breccia. Precisely the same formation is found in the cañon of the Gila, some distance to the north, about the meridian of what is called in my reconnoissance of 1846, Disappointment Creek. And no doubt, when future surveys shall develop a more minute knowledge of the physical geography of the country, each of these ranges of mountains will find their equivalent to the north and to the south. With the present information, I shall not even attempt to connect them conjecturally.

Hypothetical geography has proceeded far enough in the United States. In no country has it been carried to so great an extent, or been attended with more disastrous consequences. This pernicious system was commenced under the eminent auspices of Baron Humboldt, who, from a few excursions into Mexico attempted to figure the whole American continent.

On the same kind of unsubstantial information, maps of the whole continent have been produced, and engraved in the highest style of art, and sent forth to receive the patronage of Congress, and the applause of geographical societies, at home and abroad; while the substantial contributors to accurate geography have been overlooked and forgotten.

The San Luis range of mountains rises abruptly from the plains about three leagues north of the parallel 31° 20′, and as they run south assume by far the most formidable appearance of any range on that parallel west of the Rio Grande. They are called in Sonora and part of Chihuahua, the *Sierra Madre Mountains*, yet they do not fulfil entirely the conditions implied by that term, for I am informed that the waters flowing from their base towards the Pacific coast often take their rise to the east of these mountains, and flowing through chasms impassable for men, falling down the western slope in rapid descent producing sublime and picturesque cascades.

It is not in my power to explore this range to the south, but I was informed by persons worthy of confidence, that throughout its whole extent, as far south as the parallel of Mazatlan, it was impassable for wagons, and there was no probability of ever finding, south of 31° 20′ a

line for a railway. The report of its impracticability for wagons was confirmed by the fact that the camino real (highway) established by the Spaniards to connect Chihuahua and Guymas, makes a great circuit, and passes to the north of 31° 20′, and within what is now the territory of the United States.

This stupendous range of mountains, which drops so abruptly a few miles north of the boundary, as if to make room for the highway which is to connect the Pacific and Atlantic States, no doubt reappears to the north in the neighborhood of the Gila, but our information is not yet sufficient to establish the connection. I am quite satisfied of one thing, however, its equivalent is not to be found in what is called the Sierra Madre in New Mexico. Pursuing our course still eastward, we pass over wide plains bounded by detached ranges of the mountains, of metamorphic and other limetones, associated with igneous rocks, rich in silver and lead, and at El Paso we encounter the western flank of the third great mountain chain, the Rocky Mountains, known in that particular locality as the Organ Mountains, and at intervals of about eighty miles, we cross two other ranges, the Eagle Spring and the Limpia range of mountains. These three chains of mountains appear to be spurs of the Rocky Mountains, and are characterized by the presence of carboniferous limestone, greatly disturbed by igneous protrusions of what Professor Hall characterizes as of "comparatively modern origin." And throughout this whole region, the carboniferous and metamorphic limestone is not unfrequently traversed by rich seams of argentiferous lead ore. Between the San Luis range and the Organ Mountains, the first of the Rocky Mountain range, the metamorphism of the rocks is so complete and the irruptive lines so frequent, and their protrusion above the crust of the earth so detached, it is impossible to say, with our present information, where the one begins or the other ends, or whether they do not all belong to the same system. It is between these two ranges, upon the banks of the Janos River, that we discover the first evidences of that vast cretacious formation which has been traced from the 108th to the 101st meridian of longitude, and as far north as the great Salt Lake, and south to the 25th parallel of latitude. The western limit of this formation, discovered by the boundary survey, is the basin of the Janos River in Chihuahua; and its eastermost limit, San Antonio in Texas. How far it extends north and south has never been ascertained, but it has

been traced in one direction as far as the big Salt Lake of Utah Territory. Granite, and its associated gold-bearing rocks occur sporadically throughout the Rocky Mountain chain and its spurs, but the distinguishing feature, in an economical point of view, is the prevalence of carboniferous limestone with which is found associated argentiferous galena. Silver mines of richness have been discovered, and some of them worked to a limited extent in the mountains about Tucson, at Barrancos, Presidio del Norte, Wild Rose Pass, in the Organ Mountains, and other localities. Gold mines have been worked at the Calabasas on the Santa Cruz River, and in the mountains of New Mexico on both sides of the Rio Bravo. It will not be extravagant to predict the discovery of many localities where silver mines can be worked to advantage throughout the whole region where carboniferous limestone exists, extending on the line of boundary from the great bend of the Rio Bravo, in Texas, to the meridian of the San Luis range. Should this conjecture prove true, we shall have there in abundance the only commodity in which we are now deficient, and for which we are at all dependant upon any other country. Another argentiferous region of exceeding richness, and I think one wholly disconnected from the other, is in the basin west of the Santa Cruz River, between that river and the Gulf of California. Veins of metal were discovered interjected through a coarse sandstone.

I have stated that the eastern portion of the continent, with which we are familiar, is entirely different in its physical geography from the western, and among the distinguishing features of the first was the Alleghany chain of mountains, which sheds its waters clear from the summit to the ocean. That is to say, water once above the surface at any point continues to flow in that position until it reaches tide water. Between the two great chains which I have attempted to describe, occupying the western portion of the continent, there are other chains of mountains so numerous that it is impossible to describe them by word; some are continuous, some are detached ridges, others isolated peaks, rising from the plateau almost with the uniformity and symmetrical proportions of artificial structures. Between them are found basins which have no outlets to the ocean, but are the receptacles of the drainings of the surrounding water-sheds. Of these the most extensive is the Great Salt Lake, in Utah Territory; and the most remark-

able for its historical associations and present importance, is the valley of the City of Mexico.

This succession of basins forms a prominent feature in the Geography of North America, extending two thirds the length of it and quite one third the breadth of it. They belong to what has been appropriately designated as the basin system of North America. Those found near the boundary are Santa Maria, Guzman, and Jaqui, all to the south of the boundary and within the limits of Mexico. The first is fed by the waters of the River Santa Maria, which runs in a northern direction, and Guzman, by the river bearing the several names, Casas Grandes, San Miguel, and Janos, the general course of which is also from the south to the north, and the waters of Lake Guzman and Lake Santa Maria are said to unite in seasons of unusual freshets. The waters of the Rio Mimbres, near the same meridian as Lake Guzman, which take their rise near the Santa Rita del Cobre, run towards that lake, but they disappear in the plain to the north of the boundary before reaching it.

The waters of these Lakes or inland seas are brackish at all times, but in seasons of drought, which last two thirds of the year, they become excessively salt and wholly unpalatable. Their shores are covered with lacustrine deposits, and are usually unsuited to cultivation. The waters of these vast basins are not all locked up however by the mountains. Three great rivers, with their tributaries, have made their way in different directions to the ocean, cutting in their passage gigantic chasms in the mountains; these rivers are the Columbia, the Colorado of the west, and the Rio Bravo. Another river, the Gila, drains this plateau, cutting the mountains nearly at right angles, which although a tributary of the Colorado, joins it near its mouth, and at an elevation so little above the sea that it may in a general description, be considered a separate and independent drainage.

Another feature of this basin system remains to be described, which is also common to all the rest of the mountain regions occupying the plateau and the region lying east of the Rocky Mountains.

Between the ridges of mountains the traveller occasionally encounters vast plains, which, when the sun is above the horizon, producing the phenomena of mirage, presents to him all the appearance of the sea. The plain bounds the view and the line of the horizon is broken

into waves, resembling in appearance the edge of the Gulf Stream when seen from the deck of a vessel ten or fifteen miles distant. The plains are clothed with vegetation of a scrubby growth, incapable of affording subsistence to any but a class of small animals, such as antelopes, prairie dogs, and rabbits; most generally, however, in the southern part of the United States these plains are clothed with a luxuriant growth of Grama, the most nutritious of all the grasses. Sometimes they are destitute of all vegetation, except the Larrea Mexicana, the Yucca, the Cactus, and other spinose plants, and are paved with minute fragments of basalt, agate, and other hard rocks. Occasionally in these plains we encounter sand dunes, called by the Spaniards *Medanos*, extending over a large area of country, and encircling what might at first sight be supposed the shores of dried-up lakes. But an examination of the sand with a microscope of sufficient power dispels this idea. The grains seem to be angular, and are not rounded by the attrition of water. An extensive formation of this kind occurs between the Rio Colorado of the west and the base of the Sierra Madre, and extends many miles along the western coast of the Gulf of California. Another very extensive waste of sand lies to the south of the Arkansas River; a third is traversed by the Platte River, and a fourth which has come under my notice, less in extent, lies to the south of the Rio Bravo in the State of Chihuahua on the road from El Paso to the city of Chihuahua.

The plains or basins which I have described as occurring in the mountain system, are not the great plains of North America, which are referred to so often in the newspaper literature of the day, in the expression "News from the Plains," "Indian depredations on the Plains," etc. The Plains proper is the extensive inclined surface, reaching from the base of the Rocky Mountains to the shore of the Gulf of Mexico, and the valley of the Mississippi, and they form a feature in the geography of the western country as notable as any other west of the 100th meridian of longitude. Except on the borders of the streams which traverse these plains in their course to the valley of the Mississippi, scarcely any thing exists deserving the name of vegetation. The soil is composed of disintegrated rocks covered by a loam an inch or two in thickness, which is composed of the exuviæ of animals and decayed vegetable matter. The growth on them is principally a short but nutritious grass called buffalo grass (*Sesteria Dactyloides*). A narrow

strip of alluvial soil supporting a coarse grass and a few cotton-wood trees, marks the line of the watercourses, which of themselves are sufficiently few and far between. Whatever may be said to the contrary, these plains west of the 100th meridian are wholly unsusceptible of sustaining even a pastoral population, until you reach sufficiently far south to encounter the rain from the tropics. The precise limit of these rains I am not prepared to give; but think the Red River is perhaps as far north as they extend. South of that river the plains are covered with grass of larger and more vigorous growth. That which is most widely spread over the face of the country is the grama or mezquite grass, of which there are many varieties. This is incomparably the most nutritious grass known. South of the Red River also, the plains are not unfrequently covered with a growth of mezquite trees, (*Algarobia*,) of which there are many varieties. This tree varies in size, according to the character of the soil and quantity of rain. It is usually from fifteen to thirty feet in height, crooked, gnarled, and armed with thorns. The wood is hard and full of knots, and is unfit for purposes of carpentry; but in other respects it fulfils many of the economical uses of life. It is excellent firewood, and makes good posts, being very durable. It exudes a gum which is equal to gum arabic, but to the traveller its most important quality is the fruit which it bears, a nutritious bean much relished by animals, and not wholly unsuited to the tastes of man.

The vegetation of the mountain and basin region, while it differs materially in the genus and species of plants according to the locality, possesses, nevertheless, a general similarity which is striking and peculiar. I have described that of the plateau or levels, as consisting of a diminutive growth of shrubs, but as we ascend from these to the height of the surrounding mountains, we pass through a succession of floral products ranging in character according to the elevation to which we ascend, until we reach an Alpine flora. North of the parallel of 32°, this appears at the height of about 6,000 feet above the sea. In situations protected from the winds, we usually find at those heights pines and cedars, and at a less elevation, different varieties of oak. Wherever this region is traversed by watercourses, cotton-wood, and occasionally sycamore, grow on the edges of the streams. There are throughout this region, on the sides of the mountains, growths of pine, oak, and cedar, which are quite extended, and

present a frost-like appearance, but nowhere until we begin to descend the Pacific slope, and get within the influence of the humidity from the ocean, do we encounter timber at all approximating in size or luxuriance of growth, the forest with which we are familiar in the basin of the Mississippi and the eastern slope of the Alleghanies. The Pacific slope, — including the waters of the Sacramento and its tributaries, the Columbia and its tributaries below the Cascade range and Puget Sound and its tributaries, — it is not my intention to describe in this general sketch, further than to say, that refreshed by frequent showers and fogs from the ocean, it presents a different and more inviting picture than the country to the east of it.

It is on this slope that we find that stupendous growth of red-wood, the accounts of which appear almost fabulous. We find here, too, in all that region north of Monterey, considerable adaptation both in soil and climate, to the production of the cereal plants. About Santa Barbara, in parallel 34° north latitude, the mountains run to the sea; thence the coast deflects sharply to the east, and below or south of this point, the trade-winds, which sweep along the Pacific coast charged with humidity for nine months in the year, from as far north as the Aleutian Islands, seem to diminish in force, and finally die away at the lowest extremity of California. The mountain range at Santa Barbara cuts off these humid winds from the land to the south of them; and it is my opinion that on the Pacific slope, beyond this point, and until we reach the region of the tropical rains, no crops can be raised with any thing like certainty without irrigation. Below them the agricultural character of the country is much the same as that of the mountain and basin system, and this character is retained along the coast until we reach the parallel of Mazatlan, where the tropical rains begin to be felt in great force. For the four months (July, August, September, and October) during which I kept a meteorological record at Camp Riley, no rain fell in sufficient quantity to be measured. The mean height of the barometer for that period was 29.853; the thermometer 68.37, and the mean dew point 58°.13.

There are considerable portions of the extensive mountain system which I have attempted to describe, where wheat and rye can be raised without irrigation; but these portions are exceptions to the general rule; and I think I am safe in stating that, as a general rule, throughout this vast region, corn, cotton, and vegetables cannot be produced

without irrigation; and furthermore, the limits of the ground which can be brought under the effects of irrigation are very circumscribed.

The town of El Paso, in lat. 31° 44′ 15″.7, and long. 106° 29′ 05″.4, is considered, and justly so, one of the garden spots of the interior of the continent. A meteorological record was kept at Frontera, a few miles north of this point for two years, by Assistant Chandler, the results of which are embodied in the accompanying diagram. The whole quantity of rain for one year was only 6.4 inches. From this it will be seen how very dry the climate is, and how unsuited for agricultural purposes, according to the notions entertained of farming in the Eastern States. The settlements about El Paso are irrigated by the Rio Bravo, and are happily not dependent upon rains for their fertility.

Whatever population may now or hereafter occupy the mountain system and the plains to the east, must be dependent on mining, or grazing, or the cultivation of the grape. The country must be settled by a mining and pastoral, or wine-making population; and the whole legislation of Congress, directed heretofore so successfully towards the settlement of lands in States east of the 100th meridian of longitude, must be remodelled and reorganized to suit the new phase which life must assume under conditions so different from those to which we are accustomed.

II. PALEONTOLOGY.

1. On the Geological Position of the Deposits in which occur the Remains of the Fossil Elephant of North America. By J. W. Foster, of Monson, Mass.

The true position in the geological series of the deposits in which these remains occur is still a mooted point among American geologists. Many maintain that the introduction of the elephant upon the earth was subsequent to the Drift epoch, and there are those even who assert that their extinction has taken place since the advent of man. I am disposed to refer their origin to a far higher antiquity, when the earth

was tenanted with different forms of animal life, and when different physical conditions prevailed from what we now behold. I will proceed with some minuteness to adduce the evidence on which this opinion is based; and in the accomplishment of the task it will be necessary to inquire into the origin and age of the superficial deposits in which these remains are entombed.

From the borders of the Arctic Ocean to the limits of latitude forty degrees north, we meet with accumulations of clay, sand, and gravel, interspersed with boulders of northern origin, and blocks derived from no great distance. In the basins of the Great Lakes, these deposits consist of marly clays, variously colored, overlaid by coarse pebbles, and water-worn boulders. Intermingled with these clays are found the remains of vegetables, consisting, so far as identified, of red and white cedar, spruce, pine, and cranberry, — indicating the existence of a subarctic vegetation. Thus far, throughout the entire area occupied by these deposits, few remains of shells have been found; but these are of fresh water origin. These materials are sometimes mingled together pellmell, but are more frequently distributed in stratified beds. The boulders occupy no particular position, but appear to have been deposited sometimes upon rubble and sometimes on comminuted clay.

We are too apt to regard the Drift agency as of short continuance; and there are those who still maintain that the materials were distributed by a temporary rush of the waters; but it may be presumed that a long interval of time intervened between the first grooving and planing down of the rocks and the cessation of the boulder transportation, which observers have thus far failed to indicate by distinct geological monuments.

There are other phenomena intimately connected with the close of the Drift epoch, to which I will proceed to advert. These are the TERRACES.

To those who have investigated the terraces which border the great lakes and rivers of our country, it must appear evident that they have not resulted from the bursting of barriers at their outlets, but from the gradual rise of a portion of the continent, with sufficient pauses in the movement to admit of their formation. The oldest river terraces appear to have been formed towards the termination of the Drift period, since we find that they contain erratic and angular blocks which could not have been transported to their present position by

existing agencies. This might not necessarily follow in all instances,—for the Drift of which they are composed might have been subsequently modified by fluviatile action; but we have not the means of distinguishing between primitive and modified drift. Even those terraces composed of comminuted materials might have been formed at a time when the summits of the country were above the Drift agency, while the depressed portions were exposed to its ravages.

On the whole, it is reasonable to suppose that the most ancient of the terraces are intimately connected with the termination of the Drift epoch, and that their formation was the result of those elevatory movements by which the continents were made to assume their present outlines. When we witness the present operation of rivers in eroding their channels and forming alluvial deposits, we may well suppose that the more recent even of the terraces have a higher antiquity than that ordinarily assigned to the introduction of man.

We propose to offer a few remarks as to the physical conditions which obtained during the accumulation and dispersion of the superficial materials comprehended under the head of Drift. It is pretty well agreed among geologists that ice was the agent by which the rocks were planed down and striated, and the boulders transported; but it is not agreed whether that agency was manifested under the form of glaciers or icebergs.

For the production of glaciers several conditions must exist. The country must be diversified with mountains and valleys; the vicissitudes between the summer and winter temperature must be marked; and the atmosphere must be sufficiently charged with moisture to cause it to descend in the form of rain and snow. Hence, at this day, as pointed out by De Beaumont, we have beneath the tropics, mountains which rise above the snow-line; but there is not sufficient variableness of climate to cause the snow to descend in the form of glaciers. Hence, in Arctic America we have all the conditions of climate necessary to their production; but the relief and depression of the soil are wanting.

If we were to suppose that, preceding the Drift epoch, the country stood a few thousand feet higher than at present, the summits of the Adirondack and White Mountains would be brought within the limits of perpetual snow; glaciers might be formed, which, descending into the valleys, would groove and polish the rocks and leave behind long lines of rocky fragments known as moraines. But in the region of the West,—

where, from the southern confines of the Drift to the borders of the Arctic Ocean, there is no elevation two thousand five hundred feet above the tide-level,*—whatever might have been the conditions of the climate, glaciers would not be generated. Immense accumulations of ice would be formed in the circumpolar regions, and a sub-arctic vegetation would cover the plains and the slopes of the hills, where now we meet with deciduous trees.

While, therefore, in the more elevated portions of New England and New York, we find phenomena clearly referable to glacial action, throughout the West, we must resort to other causes to explain the planing and grooving of the rocks, the transportation of boulders, and the stratification of the superficial materials.

That the climate of both continents was much colder preceding the human epoch than at present, is evidenced by a variety of facts. The buried timber, as before remarked, is almost exclusively of a sub-arctic character. The molluscs of this period, according to Prof. E. Forbes, although belonging mainly to existing species, indicate by their assemblage the same thing. The fossil elephant of Europe, by his compound covering of wool and hair, was adapted to withstand the rigors of a northern climate; and by the augmented complexity and number of the triturating plates of his teeth, as compared with the existing species, as indicated by Owen, was adapted to live mainly on the woody fibre of trees. That the habits of the mastodon were similar, is proved by the fact that the contents of his stomach, in several instances, have been found to be composed of twigs and branches of coniferous trees which now flourish in northern latitudes, and which are identical with the buried arborescent vegetation of the Drift.

Assuming that the country was submerged — and that it has been is evidenced by the Drift deposits two thousand feet above the ocean level — the vast accumulations of ice in the circumpolar region would be set afloat, in the form of bergs, freighted with fragments of rock and finer materials incorporated with them while attached to the land, which, entering the water, would pursue a southern direction, for the reason that the cold waters of the north are constantly flowing towards the equatorial regions; nor would their course be modified to any great extent by

* The height of land between Lake Superior and the Arctic Ocean, according to Sir John Richardson, does not exceed 1,500 feet above that lake.

winds, as about seven-eighths of their surfaces must have been submerged. As they melted away in their progress, they would leave behind long trains of boulders, which subsequently, when the sea bottom was elevated, would be found strewn over an unequal surface, or imbedded in detrital materials of variable fineness. These materials, if thrown down in deep water, or exposed to the action of currents, would be assorted and stratified. Wherever the icebergs became stranded upon a reef or shoal coast, the rocks would be scratched and grooved, and long lines of pebbles and boulders would be thrown up. It is by a process like this, in our opinion, that the rocks have been grooved and the boulders distributed.

If now the country were to rise slowly, with occasional pauses in the movement, summit after summit would emerge; the ocean would recede farther and farther, leaving behind a series of coast lines and beaches, indicating its former level; estuaries would become converted into lakes; the superabundant waters would be gathered into the depressions, and the rivers would flow with increased velocity, excavating for themselves new channels and bearing into the pools the silt and sand of a former sea bottom. Terraces would be formed along the margin of the valleys, as the country rose, or the waters cut away the barriers which imprisoned them.

The lakes and pools thus formed might soon become the habitats of numerous fresh water mollusca, whose remains at this day constitute beds of shell-marl. As the lakes shoaled, either by successive depositions of detrital matter or by a lowering of their outlets, aquatic plants, such as the lilies and the rushes, would take root in the bottom, succeeded by the *chara* and the *sphagnum*, which would flourish so long as the lake beds furnished a sufficient amount of moisture. While these changes were taking place on the land, far out in the sea and along the coast lines, the same causes which had dispersed the detrital materials over higher levels might be in full activity. Thus, many of the swamps and peat marshes which have served as the sepulchres of the mastodon, may have originated at a remote epoch, as compared with the advent of man, although the associated shells belong to existing species.

We have, then, evidence of an augmentation of cold by which large icy barriers were formed, of the depression of a vast area in the northern portion of the continent, of the dispersion of boulders, of a subsequent elevation of the land, of the formation of terraces and beaches, and

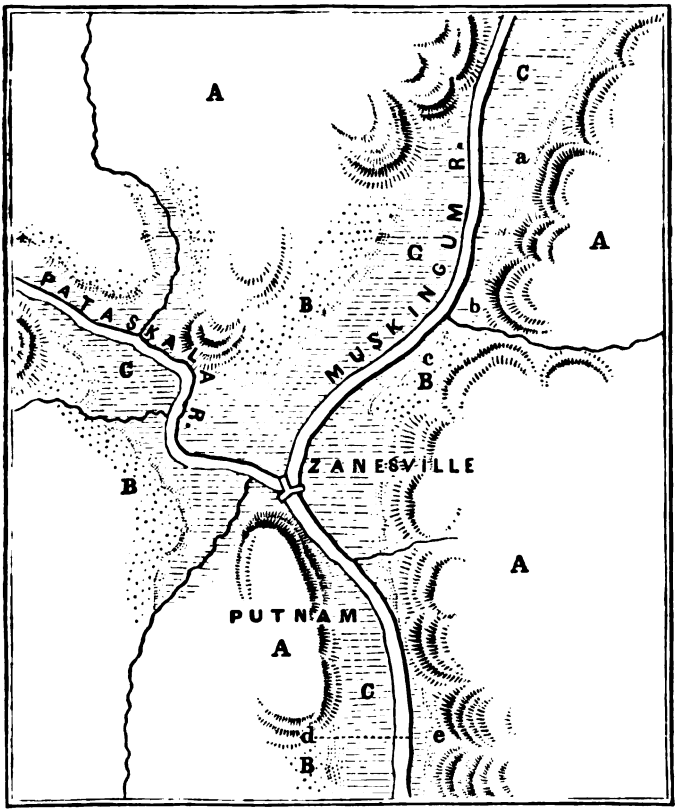
of the deposition of detrital materials, enveloping the remains of terrestrial and molluscous animals.

Having thus endeavored to sketch the peculiarities of the Drift deposits, I will now proceed to notice their connection with the remains of the elephant.

THEIR OCCURRENCE IN OHIO.

The following topographical sketch of the Muskingum Valley, near Zanesville — which is on a scale of one inch to the mile — will serve to illustrate the relative position of the several formations.

TOPOGRAPHICAL SKETCH OF THE MUSKINGUM VALLEY.



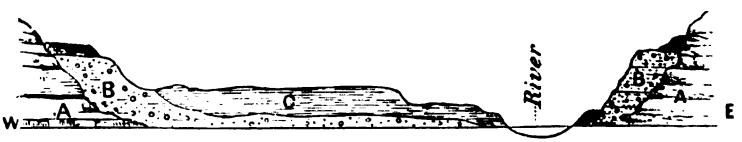
A. Coal Measures.
B. Valley Drift consisting of stratified beds of gravel, sand, and pebbles, with occasional boulders of granite, and angular blocks of limestone and sandstone, inclosing the remains of the fossil elephant.
C. Yellow loam forming the river bottom, or alluvial deposit.
a, b, c. The points in the Valley Drift where the remains of the elephant have been discovered.

That portion of the sketch (marked A) is occupied by the Coal Measures, which rise in hills two or three thousand feet in height, and present rounded outlines. The superficial soil is a clayey loam, resulting from the decomposition of the subjacent shales and sandstones, with no admixture of boulders or granite pebbles.

Skirting the flanks, and forming a well-defined terrace, sixty feet above the level of the Muskingum, is found the Valley Drift. It constitutes, for the most part, the rim of the valley, but in a few places the river has swept it away, and now impinges on the sandstones and shales of the coal-measures. The Drift reposes immediately on the subjacent rocks, which had been previously eroded, leaving an irregular surface. Its maximum thickness is sixty-three feet.

The intervening space, provincially termed "Bottom lands," consists of fine sands and clay, with an entire absence of loose blocks, boulders, or pebbles, and attains a maximum thickness of forty feet. This interval exhibits two well-defined terraces and a slight ridge, in the nature of an ôsar, which are not represented on the preceding sketch.

The following section was made across the valley, along the line *d e*.



A. Coal Measures.
B. Valley Drift.
C. Alluvium.

On the east side of the river, the rubble B is seen reposing on the flanks of the hills, while the immediate bank consists of loam C. The west bank rises abruptly from the water's edge to the height of ten feet,

succeeded by a bench about four rods in width, when there occurs a terrace about five feet in height. Another bench of about the same width then intervenes, with a terrace nine feet in height, and next a bench one-fourth of a mile in width, bounded by an oval ridge, beyond which the gravel terrace rises to the height of about twenty-six feet, capped with a layer of clay.

Proceeding north, along the left bank of the river, this terrace is soon lost sight of, and the subsequent formation (C) approaches the base of Putnam Hill.

Having rounded the point, the ancient terrace reappears in the valley of the Pataskala, forming an elevated plateau, much prized for building sites. Crossing the Pataskala, sharp and well defined, it is seen skirting the valley of the Muskingum for a mile and a half, and removed from one fourth to one half of a mile from its channel, until it intersects the rocks of the coal measures. It rises to the height of twenty-five or thirty feet above the bottom land, and then stretches back in a beautiful plateau.

Crossing to the Zanesville side, at the point E, it is seen along the flanks of the hills; but, a short distance above, the river intersects the coal-bearing rocks. At Slago's Run, the coarse gravel, cemented into a conglomerate by calcareous matter, is seen reposing upon the limestone; then succeeds an interval of nearly half a mile, over which it is obscurely traced; but above the town, at Cox's paper-mill, it reappears on the river bank in the form of a bluff sixty-three feet in height, and continues for three fourths of a mile, when it gradually recedes from the bank and assumes the form of a terrace. It is here that the observer has the best opportunity of studying its structure. Layers of fine sand alternate with layers of coarse pebbles, often intermixed with minute particles of vegetable matter. The materials are most thoroughly assorted, — a process which must have resulted from their prolonged suspension in the water. The beds of sand are freed from all aluminous matter, and often contain small pebbles of the size of a bullet, arranged along the lines of bedding. They exhibit many of the most beautiful examples of cross-stratification, which would seem to indicate that the materials were pushed along the bottom of an estuary and deposited amid shifting eddies. From the character of some of these beds, it is evident that the current by which they were deposited did not flow in the direction of the present stream.

The coarser materials consist of pebbles, rounded and smoothed, and derived from sources far remote; intermingled with angular and slightly rounded blocks from the immediate neighborhood. Among the former I recognized granite, sienite, quartz, hornblende, greenstone, yellow jasper, and black chert, together with pebbles of limestone, mainly from the Niagara group. It is not unusual to find in these loose deposits well preserved specimens of the Niagara corals, affording, in this respect, a very remarkable analogy to those of the Lake Superior region.

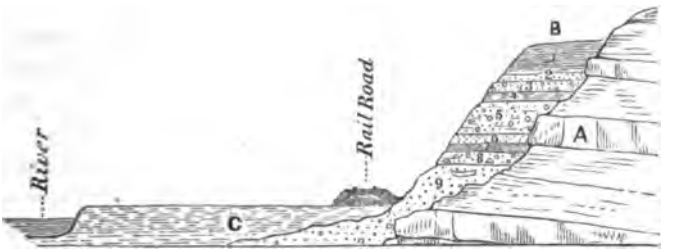
It was in this vicinity, at the point *c*, where Malinda street intersects the river, that the remains of the elephant were first discovered, about eight years since. A fragment of a tusk three feet in length was washed from the bank, and is now in the possession of Mr. James L. Cox, of Zanesville. Subsequently another was exhumed at the point *b*, near Mill Run. In December, 1852, Mr. Thomas S. Sedgwick, one of the engineers on the Central road, and Mr. Albert Spaulding, observed a portion of an incisor protruding from the bank at the point *a*, about eight feet above the railroad embankment. They soon succeeded in laying bare the two incisors, the four molars, and other fragments of the skeleton. Having heard that I was in the vicinity and was soon expected there, they suspended further operations in order to enable me to witness the exhumation, and critically examine the nature of the surrounding materials; a favor for which I desire to express publicly my sincere thanks. After my arrival, the excavations were resumed and revealed a portion of the cranium, one of the patellæ, one of the vertebræ, a rib, &c. Although, I doubt not, other portions of the skeleton might have been found, yet these bones were in so frail a state as to render them almost worthless, and, therefore, the farther prosecution of the work was abandoned.

The molars were in a high degree of preservation, and now constitute a part of the collection of the late Dr. J. C. Warren, of Boston.

The height of the elephant bed is: —

	Feet.
Above the river at the Upper bridge at Zanesville	37
Above Lake Erie	142
Above tide water	707

SECTION OF THE ELEPHANT BED.



A. Coal Measures.
B. Drift Terrace.
C. Alluvium.

	Feet.	Inches
1. Yellow loam, stratified	8	
2. Fine sand, "	1	
3. Fine gravel, "		6
4. Yellow loam, "	2	
5. Pebbles of igneous rocks, some of which are 4 inches in diameter	6	
6. Yellow sand, stratified		6
7. Yellow loam		7
8. Pebbles like bed No. 5, intermingled with large angular and slightly rounded blocks from the vicinage. Among these I observed a sandstone block, 5 feet × 1½ × 1½: — another much rounded 2½ × 1½ feet: — a slab of limestone 2 × 1½ × ½ feet: also angular blocks of chert, containing 5 or 6 cubic feet. I have observed in this connection granite boulders, containing 8 or 10 cubic feet	2	6
9. Fine yellow sand, diagonally stratified with bands of fine pebbles, inclosing the remains of the elephant.	8	6
Total	29	7

The subjacent deposits at this point are concealed by the alluvium; but farther down the stream the same alternation of coarse and fine materials is found to continue to the water's edge. Their entire thickness, as before remarked, is sixty-three feet.

The bones do not appear to have been worn or broken, previous to their deposition; and from the fact that all of the molars, and both incisors, together with the cranium, were found together, I am inclined to the opinion that the entire carcass was floated into this ancient estu-

ary, and held together by the skin and strong integuments until the more perishable materials decayed.

There is another circumstance worthy of consideration, and that is, the occurrence of large fragments of rock immediately above these remains, which we have not seen repeated elsewhere in the section. This would seem to indicate the existence of a current of unusual turbulence, or that there was a renewal of the same causes by which the boulders were transported, after the interment of the carcass.

There are two other points within the Muskingum Valley where these remains have been found. Mr. A. C. Ross has a small molar, in a high state of preservation, which was found near the mouth of Salt Creek, nine miles below Zanesville. It had been washed from the adjoining bank, but it was not traced to its source. At Beverly, forty miles below Zanesville, three molars were taken from the Valley Drift.

Let us now examine the order of events which has happened here. That order, if I rightly interpret the phenomena, was as follows: First, the valley was scooped out of the Coal Measures, which form the great framework of this region; next, it was filled from side to side, to the height of sixty feet, with sand and pebbles, and occasional boulders, — all derived from regions far remote, — and angular blocks from the vicinity, at a time when the country stood at a lower level than at present. Then the country was elevated, during which the valley was partly reëxcavated, leaving behind the drift terraces as a record of the event. Again it sunk, when the comminuted sand and clay, forming the river bottom, was deposited, and rose again at successive intervals, leaving behind no less than three sets of alluvial terraces. After the formation of the most ancient, or drift terraces, the waters ceased to transport pebbles and angular blocks. The river now winds its way through this alluvial bottom, which was formed under different physical conditions from those which now prevail; that is, when the waters were higher, or, what amounts to the same thing, when the country was lower. There is nothing to induce us to believe that these changes have taken place within the human epoch. The latest of the terraces, we may presume, are older than man; but when compared with the first formed, which contain the remains of the elephant, they are comparatively modern.

In estimating the antiquity of these deposits, we should also bear in

mind that the highest drift, and that farthest removed, is the oldest. As the country was first depressed, and then rose by repeated oscillations, it follows that the higher portions, and those the most remote from the sources of this agency, would be first exempt from its ravages. We are here near its southern confines (latitude 40° N.), and in a region where it has penetrated only through the deeper valleys; and as these deposits are situated nearly 150 feet above Lake Erie, we must assign to them a higher antiquity than the uppermost of those which occur at lower levels.

Jackson County, Ohio.

In the year 1838, Mr. Briggs and myself, then employed in the geological survey of Ohio, exhumed a portion of the skeleton of the fossil elephant from the banks of one of the tributaries of Salt Creek. The fragments consisted of two molars, several ribs, portions of the cranium, one incisor, two patellæ and several vertebræ.

These remains were found in an ancient lacustrine deposit, covered over with fine detrital materials, to the depth of eighteen feet, of which the following is a section: —

	Feet.	Inches.
1. Yellow clay or loam	5	6
2. Yellow sand	7	6
3. Irregular layers of sand shaded red and yellow, and firmly cemented with iron		8
4. Blue clay, inclosing the remains of the elephant, together with fragments of plants not identified	5	
Total	19	8

This deposit forms a bluff on one side of the stream, while on the other occurs the more recent alluvium.

The following were the dimensions of the incisor: —

	Feet.	Inches.
Length on the outer curve	10	9
Length on the inner curve	8	9
Circumference at the base	1	9
" two feet from base	1	10
" four " " "	1	11

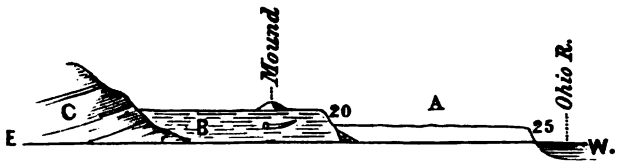
Its weight was 180 pounds; it was in a very frail condition and has since crumbled to pieces.

Western Virginia.

Mr. Alfred Sears, lately an engineer on the Baltimore and Ohio Railroad, has deposited in the museum of the Smithsonian Institution a few fragments of the skeleton of the fossil elephant, and from him I derive the following account of their geological position: —

"Above Wheeling the river bottom is very narrow; but as we descend the Ohio, it widens gradually, rising with one step until we reach a point four and a half miles from Wheeling Creek, when another step begins and continues beyond the place where these relics were found. The bottom is very level, and consists of a deposit of gravel and sand. At a point intermediate between Wheeling and the place where the cross-section occurs, other bones of the elephant were found in the 'Upper bottom,' twelve or thirteen feet below the surface."

The following is a cross-section of the Ohio valley near Wheeling: —



A. Bottom land.
B. Terrace in which the bones occur, 17 feet below the surface.
C. Coal-measures, rising in hills to the height of 200 feet.
Height of the steps is 20 — 25 feet.

With regard to the pebbles, Mr. Sears remarks that he has never seen in this part of the Ohio any of granitic origin, but they are for the most part of sandstone and limestone, the debris of the neighboring formation. Between these deposits and those of the Muskingum Valley, there is a coincidence in this respect, — that the elephant remains occur in the upper or oldest terrace; and to show that they possess a higher antiquity than the works of man, I would state that upon this upper terrace, and within a few feet, in a linear direction from the lower deposit of fossil bones, there is an aboriginal mound, thus proving that the topographical features of this vicinity must have been the same as we now behold at the time of the building of this structure.

Kentucky.

Hitherto the Big Bone Lick,* in Kentucky, has proved the great charnel-house of the remains of the mastodon and elephant. This locality has often been described as a swamp, with a substratum of blue mud, in which these colossal pachyderms, together with the bison and deer, belonging to existing species, were mired. This view, however, is erroneous. The deposits are very similar to those in Jackson county, Ohio, hitherto described,—consisting, first, of a yellow clay, fifteen or twenty feet in thickness, with a dark-colored clay below, containing the pachyderm remains. At the place where most of the excavations have been made, the yellow clay has been denuded, leaving the blue clay on the surface; and although in this swamp the bones of the deer and the buffalo have been found side by side with those of the mastodon and the elephant, yet they belong to two distinct geological epochs. The latter were entombed before the deposition of the yellow clay, and the former after its denudation. It is an undeniable fact that the pachyderm remains have been found, on penetrating

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* The occurrence of these remains at this point was mentioned by Dr. Longeuil, a French voyageur, as early as 1744.

In the Journal of Christopher Gist, an agent sent out by the Ohio Company, occurs this notice:—

"Wednesday, March 13, 1751. We set out S. 45 West down the river Ohio. I met two men belonging to Robert Smith, at whose house I lodged on this side of the Mineami (Miami), and one Hugh Crawford. The said Robert Smith had given me an order on these two men for two of the teeth of a large beast, which they were bringing from towards the Falls of the Ohio (Louisville), one of which I bought and delivered to the Ohio Company. Robert Smith informed me that about seven years ago (1744), these teeth and the bones of these large beasts, one of which was somewhat smaller than the other two, were found in a salt lick, or spring, upon a small creek which runs into the south side of the Ohio, about fifteen miles below the Great Mineami River, and mostly above the Falls of the Ohio. He assured me that the rib bones of the largest of these beasts were eleven feet long, and the skull bones six feet across the forehead, and the other bones in proportion; and that there were several teeth there, some of which he called horns (incisors), and said they were upwards of five feet long, and as much as a man well could carry; that he had hid one in a branch at some distance from the place, lest the French Indians should carry it away. The tooth which I brought in for the Ohio Company was a jaw tooth of better than fourteen pounds weight. It appeared to be the first tooth in the jaw, and looked like fine ivory when the outside was scraped off."

through the yellow clay, in the blue clay beneath; but there is no evidence that the remains of the ruminants have been found under these conditions.

I cannot, therefore, subscribe to the opinion thrown out by Sir Charles Lyell, in his Travels in North America, that the matrix of these bones is the silt deposited by the recent action of the river; but regard it as part and parcel of the Drift clays so abundantly distributed over the West, which invariably preserve the same relation, the *blue* beneath, the *yellow* above. This knowledge of the order of superposition is understood by every inhabitant of that region, and is brought into requisition in every well that is sunk. Although in the nature of lacustrine deposits, I am disposed to refer their formation to a period when the continent was rising, and the superabundant waters were gathered into the depressions of the soil, forming lakes and pools.

Illinois.

The profile of the prairies does not exhibit one uniform dead level; but a succession of elevations and depressions like the ground swell of the ocean transfixed. The culminating points attain an elevation of not over three hundred feet above Lake Michigan. The subjacent rocks are covered, for the most part, with transported materials to the depth, in some places, of two hundred feet. These consist of yellow clay and blue clay, the latter always subordinate; beds of sand and pebbles, rudely stratified, and boulders of granite, sometimes on the surface and at other times at considerable depths below.

To illustrate the character of these materials, I introduce two sections of borings made on the Chicago branch of the Illinois Central Railroad, in the spring of 1856.

SECTION AT RANTOUL.

1.	Prairie soil	3 feet.	
2.	Yellow clay	5	"
3.	Gravelly yellow clay	7	"
4.	Blue clay	51	"
5.	Sand	7	"
6.	Boulder of syenite	4	" 6 inches.
7.	Quicksand		
		77 ft.	6 in.

SECTION AT URBANNA.

1. Prairie soil	2	feet,	9 inches.
2. Yellow clay	3	"	
3. Red sand	2	"	
4. Yellow clay	30	"	5 "
5. Sand with pebbles	5	"	
	43 ft.		2 in.

Those mounds, like accumulations of Drift materials, devoid of stratification, so characteristic of New England, are here entirely wanting.

According to Dr. Stevens, in an excavation along the line of the Illinois Central Railroad, near Beaucoup, at the depth of about eighteen feet, the workmen found the remains of a mastodon in the prairie drift, below the yellow clay, in the older or reddish clay.

At Sandoval, about twenty-four miles north on the same route, other remains were found about twelve feet below, in a similar position.

At Bloomfield, Edgar county, the remains of a jaw and three teeth were found in the yellow clay, about three feet below the surface.

Near Danville, in the bluff forming the table-land of the country, the following section was observed.

1. Soil	5 feet.
2. Gravel with bones of a pachyderm	8 "
3. Clay	2 "
4. Fine washed sand, reposing on rocks of the Coal measures	2 "
	17 ft.

Canada.

The remains of the fossil elephant have thus far been found in only one instance in the Provinces, and that was at Burlington Heights, near the head of Lake Ontario. I am indebted to Mr. McQueen for the following account of the conditions under which they were found, communicated by Mr. E. Billings, of Bytown:—

"Burlington Heights is a narrow peninsula, about three fourths of a mile in length, and not more than half a furlong in width, which divides Burlington bay and the Desjardines marshes; an area of several thousand acres lying between the head of the bay and the town of Dundas, four miles distant. The marsh is still partially covered

with water; and recent experiments have shown that the bottom is a soft, floating mud, extending to a depth of eighty feet. Its present surface is scarcely above the waters of the bay. A sluggish stream from the high lands crawls down its centre, and in a deep, narrow glen, winds round the head of the peninsula into the bay, and now forms the Desjardines canal. I have no doubt that the large mass of alluvial matter has been formed by the stream in its untiring perseverance. The peninsula is one hundred and ten feet in height. The land on each side of the amphitheatre in which the marsh is inclosed rises to a great height, say one hundred and fifty feet above the level of the peninsula. The great puzzle to me is the cemented gravel; it begins at the surface, is thirty feet thick, is regularly bedded, like the strata in a limestone quarry, has a considerable dip, or inclination, and is all but impenetrable. It is as difficult to drill or blast as any limestone. The sand on which it is incumbent is too clean and too fine for building purposes; of this quality it continues for perhaps thirty feet downwards, and then turns into a loose, coarse gravel, like the beach of the lake. The bones were deposited in the fine sand, in which there is not a vestige of a shell of any description."

These cemented materials, overlying the elephant bed, having the consistency of a rock and dipping at a considerable angle lakeward, are seen on the right bank of the ravine along the Great Western Railway, several miles distant from Dundas; — thus showing that they maintain their persistency over a considerable area, and that their accumulation is due to causes which have ceased to operate.

As to the character of the fossil bones, the reader is referred to the letter of Mr. Cottle, in the Annals of Natural History, and copied in the American Journal of Science, Vol. XV. p. 282.

New England.

Hitherto the remains of the fossil elephant have been found only in Vermont. In the construction of the Rutland and Burlington Railroad the partial fragments of a skeleton were found at Mount Holly, on the very summit of the line, 1,440 feet above tide water, and 1,350 feet above Lake Champlain.* There are here the remains of a small peat

* Agassiz, Proceedings Am. Ass. 1849.

swamp; but Dr. Warren informed me during his lifetime that Mr. Henshaw, who was mainly instrumental in bringing these relics before the world, was strongly under the impression that some of the bones were taken from below a very large boulder.

There is here a deep cut through the unstratified drifts, and the surrounding hills, which attain a much higher elevation, are strewn with large boulders.

New York and New Jersey.

In New York and in New Jersey, the remains of the mastodon have been found in a high degree of preservation in beds of shell marl, on which is imposed a deposit of peat. The shells are, in all instances, of fresh water origin, and belong to existing species; but, thus far, no fragments of a skeleton of the fossil elephant have been found in this connection.* In the valley of the Ohio, however, the remains of these two classes of pachyderms have been found side by side, thus leaving no doubt that they were contemporaneous. The remains of the elephant at the West certainly occur in the drift materials which occupy the valleys, while those of the mastodon are found in what often appear to be erosions in the old drift.

The presence of the remains of fresh water shells of existing species ought not, however, to be relied upon as a proof of the extreme modern origin of these deposits, since it is an undoubted fact that, in Europe and in South America, where river and land shells occur associated with fossil mammalia, even of the Newer Pliocine period, they are found to belong to existing species. Thus at Brentford, on the Thames, the elephant remains are associated with fresh water shells of existing species. So, too, in the ossiferous caves of Brazil, the remains of extinct mammalia, like the megatherium, are associated with existing species of land shells. It, therefore, admits of no doubt that a race of mammalia has sprung into existence, flourished, and become extinct, while the land and fresh water shells have remained unchanged.†

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* For detailed information with respect to these deposits, the reader is referred to Dr. Warren's Memoir, "The Mastodon Giganteus."

† Wood on the Upper Tertiaries, Geol. Soc. 1849. Lyell's Elements, *passim.*

The Southern States.

In the region of the South, along the borders of the Atlantic and the Gulf of Mexico, there is a series of superficial deposits embracing the Lower, Middle, and Upper Tertiaries; and in the Mississippi Valley, Sir Charles Lyell has detected a deposit which he regards as the equivalent of the Löess, in which are found the remains of the mastodon.

There is, also, along the borders of the Gulf of Mexico, a wide belt of sandy materials, apparently more recent than the Newest Tertiary, which, although characterized by an entire absence of boulders, may be really contemporary with the Drift.

According to the testimony of Southern observers, to these pachyderm remains must be assigned as high an antiquity as the Newer Tertiary.

North Carolina.

From the banks of the Neuse River, Mr. T. A. Conrad, many years ago, obtained the bones of the mastodon, the elephant, the hippopotamus, the horse, the deer, and the elk, all belonging to extinct species, in a bed equivalent to the Upper Tertiary, covered over by a deposit of marine shells, in places fifteen feet thick, which belong to the Pleistocine period. The bones were very much water-worn, so that in many instances the characteristic differences of the animals to which they belonged could not be recognized. In conversing with him on the subject, he assured me, in the strongest terms, that these remains, as thus disclosed, belong to the Upper Tertiary; and their rolled appearance would seem to indicate that they might have been washed from a bed of greater antiquity than that in which they were deposited.

South Carolina.

Mr. Tuomey, in his Geology of South Carolina, regards the mastodon as characteristic of the Upper Tertiary; and states that forty-six per cent. of the associated marine shells are found to be extinct. In a private note, he remarks: "It is very difficult to arrive at correct conclusions as to the precise position of these remains where you do not find them yourself. I am, however, satisfied that both the mastodon and the mammoth lived at the period of the deposition of what we call in Virginia the Miocene."

In a subsequent note he embodies the following information: —

"Fragments of a tusk of one of these animals have been found in a cave in North Alabama, together with bones of the megalonyx, as determined by Dr. Leidy.

"I have a tooth of the mammoth, said to be from the Miocene of Maryland. It was found by a highly intelligent gentleman, whilst engaged in marling operations, and transmitted to Edward Ruffin, Esq. of Virginia. An account of its discovery will be found in the *Farmer's Register*. I have also a tooth and portion of a tusk of a mastodon found in the same formation in Virginia. Aside from the testimony of the respectable gentleman to whom I am indebted for these specimens, the marl attached to them, as well as their color, left no doubt in my mind as to the deposit in which they were found.

"I placed in the cabinet of the South Carolina College a fine tooth of a mastodon found under similar circumstances, in Darlington District, South Carolina. Other specimens were found overlying the Eocene, near the Santee Canal, but these, I believe, are not supposed to be derived from that formation.

"At several localities in Alabama, remains of the mastodon occur in superficial deposits."

California.

The remains of the fossil elephant have been found in numerous instances in this region, and under circumstances which leave no doubt as to their true geological position, that is, in the gold-producing drifts; — the same association having been observed by Sir Roderick Murchison, in Siberia.

Mr. Smith, connected with one of the Pacific Explorations, showed me a tooth of the fossil elephant, supposed to have been derived from one of the lignite beds of Oregon.

Foreign Localities.

The pachyderm remains found in the Pampas of South America, according to M. D'Orbignay, occupy a position intermediate between the Tertiary and Diluvial formations, which he designates Pampéen.

In Europe, the *Elephas primigenius* had a wide geographical range. Its remains have been found from the Arctic Sea to the Mediterranean. It there originated early in the Newer Pliocine, and survived through

the whole of the Glacial epoch, and perhaps even until after the period of the Terraces; for its remains are found, for example, in the cliffs of Norfolk, England, beneath the drift, in the Löess of Northern Germany, and in the ice cliffs near the mouth of the Lena, where they must have been encased at a time when that portion of the continent had assumed nearly its present level.

There are two localities in the British Isles, where the bones of the elephant have been found entombed in fluviatile or lacustrine deposits, supposed to be above the Drift. "It is not difficult to conceive," remarks De la Béche (Geological Observer), "that these mammals may have revisited the British Isles, again connected with the mainland, (supposing that the area had been submerged and again elevated), so that their remains may be found in lacustrine and fluviatile deposits, above the marine accumulations formed during the interval of depression. . . . Assuming only one submergence sufficient to disconnect the British Isles, followed by an elevation sufficient to restore the connection, it would be inferred that lacustrine and fluviatile accumulations would be the highest amid which we should expect to discover the remains of the *Elephas primigenius* and his contemporary mammals."

It has hitherto been asserted by almost every osteologist that the elephant of this country was identical with that of Europe. This, however, as will be shown in a subsequent part of this article, is a matter of exceeding doubt. If, however, this should be found true, and if the prevailing notions as to the simultaneous origin of species in different parts of the earth be correct, we are authorized in the inference, that the elephant appeared as early, and survived as long on this continent as on the eastern, and that the causes, whatever they may have been, which led to his extinction, were not local but general in their operation.

In bulk the American elephant far surpassed the existing species, and was adapted to a wide geographical range. Contemporary with him was the mastodon (*M. giganteus*), of a more ponderous frame, but of an inferior size. The fossil beaver (*Castoroides ohioensis*), tenanted the streams and lakes. Herds of cattle (*Bos bombifrons* and *Bison latifrons, L.*), roamed over the plains, while the tapir wallowed in the swamps. In the milder regions of the south, visited by the elephant and the mastodon in their migrations, lived the great

leaf-eating megatherium, the mylodon, the megalonyx, the hippopotamus, the horse, the elk, and the deer, all belonging to extinct species; while at the head of the carnivora stood the colossal lion (*Felis atrox*, L.), which then, as now, was monarch of the forest.

The observations made in the Southern States would seem to indicate that the elephant originated during the Newer Pliocene period; but my own observations lead me to infer that he commenced his existence before the drift agencies had entirely ceased; when the waters stood at a higher level, when the contours of the continent were different, when a different climate prevailed, and when a subarctic vegetation stretched far towards the tropics; at a time when the valleys had been excavated by the retiring waters, and the streams had assumed nearly their present direction. It was a period of erosion, which ought to be marked by distinct geological monuments. I would designate it as the FLUVIATILE PERIOD.

Although, in rare instances, the remains of the elephant and the mastodon have been found side by side, there are deposits, in which elephant remains are entombed, apparently older than any that contain those of the mastodon; and at the same time, there are deposits apparently newer, which contain the mastodon, in which those of the elephant have never been found. The inference therefore might be drawn, that, although at one time contemporary, the one was introduced earlier, while the other survived later.

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2. NOTE ON THE TEETH OF AN ELEPHANT DISCOVERED NEAR ZANESVILLE, OHIO. By Professor J. WYMAN, of Cambridge.

THOSE who have studied the remains of the American mastodon and elephant, must have been struck with the fact, that while the bones of the former, and even many entire skeletons, have been brought to light, in a state of nearly complete preservation, those of the latter have nearly all decayed, so that no considerable portion, such as a limb, or even an entire cranium has as yet been described. We know the existence of the American elephant at present almost entirely by the

teeth and trunk alone, and these have been thus far so imperfectly described that the modifications which they undergo in the dental series remain to be determined.

The four remarkably well preserved molars of the American elephant or mammoth, which have been referred to me by Mr. Foster, are important additions to the discovered remains of these animals. They were found together, in apposition, with some fragments of a cranium, under such circumstances as to leave no doubt that they all belonged to one and the same individual. Some fragments of tusks, but no other teeth, were seen with them. Their great size, and the number of laminæ, indicate that they were ultimate or sixth molars, so that the last members of the dental series had been brought into use. A complete series of ultimate molars, from the same individual, has not been hitherto described; usually only single ones having been found at a time. A conception of the great size of the Zanesville specimens may be formed from the fact that the aggregate weight of the jaw, in a dried state, was fifty-four pounds.

The following are the dimensions of the right and left upper molars: —

	Right. Inches.	Left. Inches.
Greatest length	13¼	13½
Greatest height, when resting on the grinding surface	10½	11
Length of grinding surface	8¾	9
Breadth of " "	4¼	4¼
Whole number of laminæ	29	30
Laminæ of grinding surface	18	18

The weight of the right tooth was fifteen pounds, and that of the left, seventeen pounds and eight ounces.

The whole number of laminæ was probably larger originally, as there are indications that some of them have been ground out; still they are more numerous than in any described tooth. The largest number hitherto described is twenty-six.*

The lower molars are longer and not so high as the upper; the grinding surface is concave instead of convex as above. It seems probable from the conditions of the teeth, that a portion of the anterior extremity had been worn off, and that the number of plates may have been originally greater.

* Owen. British Fossil Mammalia and Birds, p. 225.

	Right. Inches.	Left. Inches.
Whole length	14½	15
Length of grinding surface	9	8¾
Breadth of " "	3¾	3½
Whole number of laminæ	24	25
Laminæ of grinding surface	17	17

The weight of each lower molar was eleven pounds. Professor Owen has described a specimen,* larger than either of these, it having been sixteen inches long, and provided with twenty-eight plates.

The tusks I have had no opportunity of examining. They were seen by Mr. Foster, who found the longest fragment about eight feet long. The extremity was gone, but from the form and proportions of the part examined, Mr. Foster estimated the entire length to be about twelve feet. The tusks were much less covered than in *E. primigenius.*

Is the mammoth of America specifically distinct from that of the Old World? Owen regards them as identical. Dekay believes the American mammoth to be a distinct species, on the ground, that in a tooth examined by him, the number of laminæ was greater than in the elephant of Europe or Siberia. Thus far observations are not sufficiently extensive to determine this question. The character derived from the number of laminæ is not exact, since the range of variation is very great, and the larger the tooth, the greater the range. A correct conclusion can be reached only by examining a large number of corresponding teeth in the mammoths of the Old World and the New. It is very probable that the entire cranium, when it is discovered, will serve to settle this question. Among the Siberia fossils described by Falconer and Coutley, the crania of the different species of elephant were highly characteristic, each species having its own peculiarities strikingly marked and well defined. The theory of the identity of the species of mammoths of the Old World and the New is afforded by the analogies of the geological distribution of other Pachyderms. If the theory be correct, then we have one and the same species extending through fifty degrees of latitude, and more than two hundred and eighty degrees of longitude; in fact through the whole habitable portion of the northern hemisphere above the twentieth parallel. The

* Owen. British Fossil Mammalia and Birds, p. 225.

mastodons of America are different from those of Europe; and those from South America are different from those of North America. The sevree, the tapirs, the rhinoceros, the bison, the ox, and the lion, found fossil on this continent are specifically distinct from any of the species found in the eastern hemisphere. The elephant of Africa constitutes a species distinct from that of Asia, and the Sivalic fauna shows the coexistence of many species in one and the same geographical region even. But there are no facts which go to show that any of the species of pachyderms have so wide a distribution as that assumed for the *E. primigenius*, when it is asserted that it is common to the two hemispheres. Under the circumstances, before asserting either the specific identity or the difference of the remains in question, it is better to wait for further developments, which will, in time, no doubt, furnish the necessary evidence.

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3. On a Batrachian Reptile from the Coal Formation. By Professor Jeffries Wyman, of Cambridge.

The remains described in this connection, were recently discovered in the coal-fields of Ohio, by Dr. J. S. Newberry. Those which were most complete consisted of a nearly entire skeleton of a salamandroid animal, imbedded in the matrix, and seen from below, about five inches in length, exclusive of the tail, which had been broken off. The vertebral column between the proboscis and the head, consisted of between twenty and thirty pieces, which were quite small, and without any indications of having transverse processes which characterize batrachians, or of ribs. The head was broader and much more expanded transversely than in salamandroids or tathyoids, and more closely resembled the cranium of frogs. As in these last, the pterygoids were slender near the median line, but broad externally, the orbits large, and the angles of the jaws projected backwards beyond the occiput. The head is nearly as broad as long, and the jaws are quite regularly arched. A few simple pointed teeth were visible in the intermaxillaries, but there were no indications that there existed any pieces interposed between the lower jaws at the symphysis, as is the case in frogs and toads. The bones of the limbs correspond with those of urodels,

the humerus and femur being hollow at the ends, and the bones of the forearm remaining separate and movable on each other, instead of being consolidated as in Anourous Batrachians. The number of toes appeared to be five for each foot, though there was some uncertainty in regard to those of the fore foot.

Slight traces of a scapular order were visible, but too indistinct to indicate the anatomical structure.

If it should prove true that these animals had five toes before as well as behind, the foot-prints from the coal, which have been described as having the same number, would meet with a satisfactory explanation. No living Batrachian has more than four toes before.

The indications in this country, of the existence of reptiles during the coal period, which have been already described, are the *Cheirotheran* foot-prints discovered by Dr. King; those of the *Sauropus*, by Mr. Lea, and others discovered by Professor H. D. Rogers. In addition to these, may be enumerated the bones of the *Dendrerpeton* obtained from the cavity of a coal tree, by Sir Charles Lyell and Professor Dawson; and the *Baphetes* discovered by Mr. Dawson, and described by Professor Owen.

A portion of the remains of another skeleton was also discovered, consisting of thirteen vertebræ, with the corresponding pieces of ribs, all of which were of the same size and development, as is the case with those from serpent-like animals. The vertebræ were nearly destitute of spinous processes, but the articulating processes were broad and expanded, and in this respect bearing some resemblance to those of menopoma. The vertebral ends of the ribs were not bifurcotal as in salamanders, nor broad and expanded, as in some tathyoids. No transverse processes were visible on the vertebræ. The ribs were flattened, of nearly equal breadth throughout, distinctly grooved on the side, and strongly curved. In these respects they differ very materially from any known Batrachians, and more clearly resemble the serpents, or serpent-like lizards. The animal may have been a true Batrachian with ophidian characters superadded, just as Lepidosteus is a true fish, with certain reptilian features developed.

The remains of the two animals just described are of great interest, since they form important additions to the scanty evidence already existing of the creation of air-breathing animals as far back as the coal period.

4. Remarks on a Specimen of Fossil Wood from the Devonian Rocks, (*Gaspé Sandstones*) of Gaspe, Canada East. By J. W. Dawson, Principal of the McGill College, Montreal.

This specimen was discovered by Sir W. E. Logan, in 1844, in the sandstones and shales near Brachaut Bay, described in his Report of progress for that year, and containing carbonized comminuted plants, and other imperfect vegetable remains. These beds were ascertained by Sir William to underlie unconformably the lowest carboniferous rocks, and to form a portion of the Devonian System.

The trunk was originally about four feet in length, and several large fragments of it have been placed by Sir William in the collection of the Canadian Survey. The largest and best preserved of these fragments is seven inches in length, and nine and one half inches in its greatest diameter. It is perfectly silicified, with the exception of a thin coating of smooth coal, perhaps representing the bark. The color is black, and the texture very compact, with the exception of a tendency to split into concentric layers, the surfaces of which are thinly varnished with carbonaceous matter. These layers are shown by microscopic examination to be rings of annual growth. The thicker end of the fossil has, like the circumference, a smooth carbonaceous coating in part, giving it the appearance of having been the base of the stem. This may, however, be accidental, more especially as other surfaces, evidently not external, have thin coaly films, perhaps resulting from bituminous infiltration.

The *cross section* exhibits a well preserved and uniform cellular tissue. The cells are almost perfectly circular, not crowded, and imbedded in a semi-transparent silicious paste without structure. The limits of the rings of growth are well defined, being marked by cells of smaller diameter and more irregularly distributed than the others. The medullary rays are indicated by a few radiating cracks filled with silicious matter without structure, and by a slight tendency to a radiating arrangement of the cells. The growth rings, where best preserved, are about a line in average breadth. (Figs. 1, 2, 3).

Fossil Wood from Devonian System, Gaspé, Canada East.

Fig. 1.

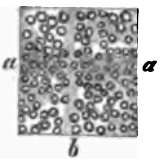


Fig. 2.

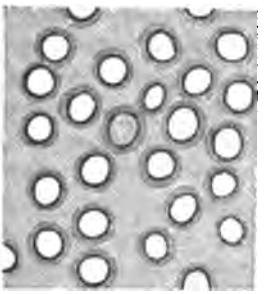


Fig. 3.

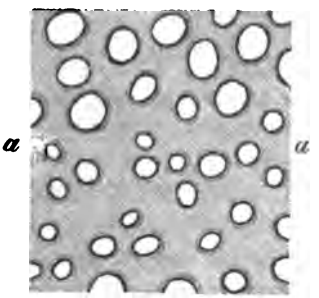
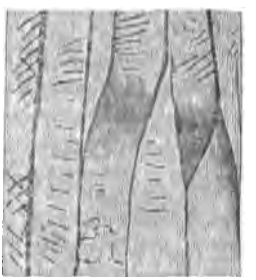


Fig. 4.



1. Transverse slice, 60 diameters, (*a*) growth line, (*b*) medullary ray.
2. " " 300 " in middle of growth ring.
3. " " 300 " (*a*) outer margin of growth ring.
4. Longitudinal section in direction of medullary rays.

In the *longitudinal section*, parallel to the medullary rays, the cells are seen to be much elongated and to terminate in conical points. Under a high power, they show traces of transverse and diagonal fibres, sometimes decussating. No medullary rays nor disc structures are visible. (Fig. 4.)

At first sight the transverse section resembles the outer cellular cylinder of Lepidodendron, or of some Lycopodia; but the apparent uniformity of the tissue throughout the trunk, the rings of annual growth, and the character of the longitudinal section, point to the conifers.

The absence of disc structure from a tissue so well preserved, weighs against this; but Professor Gray has observed* that, in the American Yew, where there are few discs, delicate spiral markings like those in the present fossil appear in their place. The young wood of some recent conifers, as, for example the Chili Pine, gives in the cross section a tissue approaching in the roundness and separation of the cell-openings to the present specimen. The fragment of fossil wood from the Devonian Rocks of Cromarty, figured by Miller, does not very closely resemble that from Gaspé; but it has been too much compressed to admit of satisfactory comparison.

On the whole, it seems probable that this ancient tree was a conifer or closely allied to the conifers; though in so far as my knowledge and means of reference extend, it differs materially from any previously observed form.

NOTE. — Since this paper was read, I have observed in Murchison's Siluria, page 358, a quotation from a letter of Professor Unger, referring to fossil plants from the Devonian "cypridina schists" of Saalfield, in Meiningen. Among these are some which seem to be primitive forms of cycads and conifers, possessing characters of which, says the Professor, no one has yet had any idea; and some present such a singular organization that he terms them the "prototypes of the Gymnosperms." It is quite probable that among the plants thus characterized there may be forms similar to the Gaspé fossil.

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5. OBSERVATIONS ON THE GENUS ARCHIMEDES, OR FENESTELLA, WITH DESCRIPTIONS OF SPECIES, ETC. By Professor JAMES HALL, of Albany.

THE term "Archimedes" has long been in use among American geologists; and is the generic name given by Le Sueur to a Bryozoan composed of broad, reticulate expansions, which are spirally arranged around an elongated axis, or stem. The axis is solid, or irregularly cellular in its interior structure; the expanded portions have the general character of *Fenestella* upon the lower or external side, while the upper

* Botanical Text-Book, fourth edition, page 46.

and inner side is in like manner celluliferous. The cellules are cylindrical, with circular or sub-circular mouths, arranged along the branches in two or more rows; branches rounded or angular above, connected by transverse processes, leaving oval or sub-quadrangular interstices.

In all the essential characters, the foliate expansions of *Archimedes* corresponds to *Fenestella*, according to the extended description of this genus by Mr. Lonsdale; and in detached fragments cannot be distinguished generically from other forms of the same genus. Some of the species have more than a double row of cells on the branches, and correspond to the genus *Polypora* of McCoy, but, nevertheless, that character is found in true Fenestella, according to the description above cited.

The mode of growth, therefore, constitutes the only reliable character for separating *Archimedes* from *Fenestella;* and should this character be hereafter considered of sufficient importance, I propose to retain Le Sueur's original name "ARCHIMEDES."

Dr. D. D. Owen has several times alluded to the "*Archimedes*" in his various Reports; and in a paper published in the American Journal of Science and Arts, vol. 43, p. 19, he gives a figure of one of the species as the "Archimedes of Le Sueur," but suggests that "it may be only a new species of Retchporea."

This figure of Dr. Owen is of a large species; but being merely the spiral axis, furnishes no characters for specific identification. It retains the thickened base of the foliate expansion, and where this is broken through presents the irregularly cellular structure, common to the axis of all the species. This structural character, or the remains of fenestrules on the edges of the spire, as seen in Dr. Owen's figure, have been mistaken by M. D'Orbigny for the animal cells; and upon this character he proposes a new genus "*Archimedipora,*" having the cells arranged upon the salient angles of the spiral band, and places the fossil in the Devonian System. No such fossil is known to occur in the Devonian System in this country. His description is, "cellules longues, placées aux saillant d'une spirale, autour d'une tige allongée." It is quite unnecessary to say that the Archimedes of the carboniferous limestones exhibit no characters corresponding to this description; and the paleontologists of our country who are disposed to adopt the name of "*Archimedipora*" will do well to compare the generic characters given by M. D'Orbigny with the fossil itself.

Below are given some of the characters of a few species known to me at the present time. These are given here for the purpose of calling the attention of geologists and collectors to these fossils, with a hope that they may prove useful in the identification of strata, and that materials may be obtained for a more complete illustration of this peculiar group of *Fenestellidæ*.

FENESTELLA (*Archimedes*) OWENANA. Axis slender, the spire rapidly ascending; branches rounded and sub-angular on the celluliferous side; cells in two rows, one on each side of the branches; connecting processes slender, and rather distant.

In the Keokuk limestone, Keokuk, Iowa, and at Appanoose, Illinois.

FENESTELLA (*Archimedes*) WORTHENI. Axis strong, robust, having a little more than three turns of the spiral to an inch, where the axis is one fourth inch in diameter; expanded portion with small oval fenestrules, and strong, closely arranged connecting processes. Branches rounded on the celluliferous side, with a faint, sharp, meandering ridge down the middle, which is sometimes thickened; rows of cells two or more. Cells sometimes occur on the connecting processes.

In the Warsaw limestone, Warsaw, Illinois.

FENESTELLA (*Archimedes*) SWALLOVANA. Axis slender, finely striated; spiral rapidly ascending, about six turns in an inch, where the axis is one eighth inch in diameter; branches comparatively strong, rounded below, sub-angular above; connecting processes slender; cells in two rows near the base, — outer ones unknown.

In the limestones of Kaskaskia and Chester, Illinois, and Crittenden county, Kentucky.

FENESTELLA (*Archimedes*) MEEKANA. Axis slender, dextral, rapidly ascending; making five revolutions of the spiral in an inch, where the diameter is one sixteenth of an inch; fenestrules oval or oblong; cells in two rows, there being two on each side of the branch in the space of each fenestrule, and rarely another at the junction of the connecting process with the branch.

This species is much more slender than either of the preceding, and is readily distinguished by the rapidly ascending spire.

In the Kaskaskia limestone, Chester, Illinois.

FENESTELLA (*Archimedes*) LAXA. Axis very slender, sinistral, rapidly ascending, making one revolution in an inch; fenestrules oblong-

oval or subquadrangular; cells in two rows, closely arranged; apertures elevated; axis and exterior of branches finely striated.

In the Kaskaskia limestone, Chester, Illinois.

There are other species, of which I have fragments too imperfect for a satisfactory determination. The direction of the spiral axis may be either dextral or sinestral, in different species, and we have evidence that this character differs in the same species, and in the same individual.

There are, likewise, other forms of Fenestella in the Kaskaskia limestone, in which the reticulate expansion is arranged between the branches of a strong stem, which bifurcates from the base: and others in which this thickened portion, corresponding to the axis of those above described, occurs only on one side. Were the axis, or strong support, to give the character, these species would constitute a group equally distinct, as ARCHIMEDES, from the usual forms of FENESTELLA, and which might be designated under the name of LYROPORA, possessing the following characters.

Bryozoum consisting of foliate reticulated expansions, margined on either side by strong stony supports which diverge from the base, curving outwards and upwards. The foliate expansion is spread out between these diverging arms, which are themselves formed by the coalescing and thickening of the branches.

The growth of these stony supports is sometimes direct, or in a line parallel with the point of attachment; and in other species there is first a receding of the whole from that point, an extreme thickening of the support on one side, and a gradual narrowing to the opposite margin where the branches originate.*

FENESTELLA (*Lyropora*) LYRA. Bryozoum composed of strong, solid, or stony support which bifurcates from a slender base, and, curving at first abruptly outward and upwards, continues gradually diverging above; the space between the two branches occupied by a reticulate expansion, consisting of strong diverging branches and more slender connecting processes, leaving small oval or round-oval interstices; surfaces of branches rounded, marked by four or five rows of cells.

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* These bifurcating processes, with the point of attachment, resemble the lower jaw of the common frog, and are known along the Mississippi valley as the "Frog-mouth coral."

In the Kaskaskia limestone, Chester and Kaskaskia, Illinois.

FENESTELLA (*Lyropora*) QUINCUNCIALIS. Base strong, broadly rounded, point of attachment obtuse; fenestrules on the non-poriferous side nearly round, on the poriferous side subquadrangular; branches slender, divergent, and bifurcating, on the celluliferous side rounded, with an irregular double row of cellules, and sometimes only a simple row on the centre of the branch.

The cellules are usually arranged one on each side of the branch in the middle of the fenestrule, and one on each side at the junction of the connecting process, which are more conspicuous than the others; thus giving one more conspicuous cellule in each angle of the fenestrule. This arrangement, and the oblique direction of the branches, give a beautiful quincunx arrangement to both cellules and fenestrules.

FENESTELLA (*Lyropora*) SUBQUADRANS. Bryozoum, with the lateral supports nearly direct from the base, diverging at an angle of more than 80°; foliate expansion extending beyond the lateral processes; branches somewhat strong and rounded on the non-poriferous side; connecting processes short; branches on the poriferous side flattened, with the pores somewhat irregularly distributed in four rows; fenestrules on the non-poriferous side somewhat oblong-oval, or subquadrangular; fenestrules on the poriferous side oval, smaller than on the non-poriferous side.

In the Kaskaskia limestone, Chester, Illinois.

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6. On the Relations of the Fossil Fishes of the Sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic Periods. By W. C. Redfield, of New York.

In the publications of Professor W. B. Rogers, and Mr. E. Hitchcock, Jr., on the red sandstone formations of Connecticut, New Jersey, and other States, founded on some of their contained fossils, a higher geological position than that of the new red sandstone has been as-

signed by these writers.* Without questioning their conclusions, I would state that we consider the fossil fishes of these rocks as the most characteristic and reliable fossils for determining the age of the formation. The determinative value of these fossils is perhaps enhanced, also, by the small vertical range to which some of the species, and at least one of the genera, are probably limited. But these fishes, although numerous, as well as characteristic, do not appear to have been referred to, in any manner, by the above-named writers.

Attention is invited, therefore, to a descriptive account of one genus or group of these fishes, which was read to the New York Lyceum of Natural History, in December, 1836, by Mr. John H. Redfield, and is found in Vol. IV. of the Annals of that Society. It was founded

* Professor W. B. Rogers, on the age of the coal rocks of Eastern Virginia. *Am. Jour. of Science*, Vol. XLIII. p. 175, (1842). Also, in Proceedings of the Boston Society of Natural History, Vol. V. p. 14, (1854), *E. Hitchcock, Jr., M. D., in Am. Jour. of Science*, Vol. XX. (N. S.), p. 22, (1855).

Professor Rogers first assigns to the coal rocks of Eastern Virginia a position near the bottom of the oolite formation of Europe, while from some fossils "discovered in a particular division of the new red sandstone of Virginia," he expects to be able confidently to announce the "existence of beds corresponding to the *Keuper* in Europe;" doubtless in the extensions of the New Jersey Sandstones or *Newark Group*. I propose the latter designation as a convenient name for these rocks, and those of the Connecticut Valley, with which they are thoroughly identified by footprints and other fossils, and I would include also, the contemporaneous sandstones of Virginia and North Carolina.

At a later period, (1854,) Professor Rogers recognizes the general equivalency of the Eastern and Middle Belts of Virginia, and the Eastern or Deep River Coal Belt of North Carolina, all of which, in his view, ought to be placed in the Jurassic series, not far probably above its base. In relation to the more western belt, the occurrence of *Posidoniæ* and *Cyprideæ*, in Pennsylvania, with sauroid coprolites and imperfect impressions of leaves of Zamites, he considers as sufficient to identify, as one formation, the disconnected tracts of this belt in North Carolina and Virginia, and the prolonged area of the so-called New Red Sandstone of Maryland, Pennsylvania, and New Jersey; and that they are of Jurassic date, but little anterior to the coal rocks of Eastern Virginia.

Professor H. D. Rogers (1839) proposed the name of *Middle Secondary* to this group (for convenience' sake), to distinguish it from the Appalachian formations on the one hand, and from the green sand deposits on the other. — *Third Report on Geology of Pennsylvania*, p. 12.

Mr. Hitchcock describes a new species of *Clathopteris* discovered in the sandstone of the Connecticut Valley. This fossil fern, found near the middle of the series in Massachusetts, he refers to the Liassic period.

upon a careful comparison of the genus *Catopterus* with the fossil fishes of different formations in Europe, as these are portrayed in the great work of Professor Agassiz, then recently received. Such portions of the description and observations then made as relate directly to the geological age of the formation will now be quoted.

Of the genus *Catopterus*, species *C. gracilis*, he says: "Tail forked, equilobed; scales extending a little upon the base of the upper lobe." And in regard to the equilobed tail, he adds, in a subjoined note: "This indeed is not *strictly* the case. Its structure, however, is analogous to that of the *Semionotus*, ranked by Agassiz among the *Homocerci*, and differs most decidedly from that of the true *Heterocerci*, where the scales, and probably the vertebræ, extend to the extreme point of the upper lobe." He adds:—

"In the arrangement of Agassiz, this fish would be comprehended in the order *Ganoides*, and family *Lepidoides*. Its equilobed tail would assign it to the second division of the family, the *Homocerci*, as he has termed them. From seven fusiform genera now arranged in this division, it is entirely excluded by the posterior position of its dorsal. It may therefore be ranked between the genera *Semionotus* and *Pholidophorus*, being analogous to both in the structure of the tail, and in its serrated fins, and to the latter, in the articulation of the rays. From the situation of the dorsal fin, I have thought the name *Catopterus* to be applicable to this new genus."—*Annals Lyc. Nat. Hist.* Vol. IV. pp. 38 and 39.

Nearly twenty years have elapsed since the promulgation of these careful and apparently conclusive observations, which do not appear to have been weakened or set aside by any subsequent researches. It is proper to state that the two analogous genera above mentioned, are found in the oolitic series as well as in the lias, and it is believed that few or none of the kindred genera have a lower range.* The above

* A single case of semi-heterocercal structure as occurring in the coal rocks of Autun in France, was mentioned to us by Professor Agassiz, in 1846. As we learn nothing more of its appearance in the palæozoic series, may there not possibly be an error as regards the authenticity or position of this fish? If otherwise, it does not seem to have appeared again until after the Permian period. On the other hand, it appears to be admitted that the true heterocerques, of the Palæoniscus type, do not appear above the Trias, and I think they are not found above the Permian.

It should be noted that Sir P. Egerton has described a most singular fish from

observations afford at least sufficient warrant for the cautious, and perhaps too limited inferences with which Mr. Redfield's paper in the Annals is concluded, namely: —

"It has of late years been generally admitted that the sandstone from which these fishes are derived is of much later date than the old red sandstone, to which it was once referred, and these remains confirm this belief. The *Palæonisci* of Europe (true heterocerques), have never been found below the coal-measures, while they extend upward to the copper slate of the *Zechstein* or magnesian limestone. In the case before us, we find a species of *Palæoniscus* (Ischypterus) accompanied by a fish, the structure of whose tail approaches that of the *Pholidophorus*, and of other fishes never found below the lias. This fact would seem to imply for this formation, even a higher situation in the series than that which is now assigned it by geologists." — *Annals, etc.* p. 40.

The American Association of Geologists and Naturalists at the meeting held in Albany, in April, 1843, requested Mr. John H. Redfield to prepare a report on the fossil fishes of the United States. His report was presented to the Association at New Haven in May, 1845. It was withheld from publication by its author on account of the expected visit of Professor Agassiz to this country, and with a view of commending the whole subject to his examination. In the review of the fishes of our new red sandstone, so called, the report stated as follows: —

"New Red Sandstone. — Under this term I include the extensive sandstone formation of the Connecticut River Valley; the small and isolated basin on the Pomperaug River, near Southbury, Conn.; the New Jersey sandstone, extending from the border of the Hudson River south-westerly, to the interior of Virginia; and, also, the formation known as the Coal Rocks of Eastern Virginia." — *Report*, p. 4.

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the upper strata of the new red, of a genus hitherto unknown, which has but little irregularity in the structure of its caudal base. This fish, the *Dipteronotus cyphus, Eg.* is very short and broad, with a double dorsal, and is altogether so *unique* in its character, that its occurrence may be deemed to affect but little the chronologic inferences which are drawn from the varied structure of the numerous genera and species of the Lepidoid family. — See *Geological Journal*, 1854, p. 369: *With a figure.* — W. C. R.

"All the fishes hitherto found in these rocks belong to the order *Ganoidæ*, and to the family *Lepidoidæ*." — *Report*, p. 5.

"Professor Agassiz has made two subdivisions in this, as in other families of the order *Ganoidæ*, founded on differences in the structure of the tail. In the first of these, (*Heterocerci*,) the upper lobe of the tail is vertebrated, and is usually longer than the lower, and the scales of the body extend upon the upper lobe nearly or quite to its extremity. The other division, the *homocerci*, have the tail regular, either forked or rounded, and the scales do not extend upon the upper lobe; though in some genera they are slightly prolonged in that direction. The fishes of our sandstone formations above mentioned would seem to belong to the first of these divisions, or those with heterocercal tails. They do not, however, exhibit this structure in the same degree which obtains in the fishes of the older European rocks, or even in those of the new red sandstone or magnesian limestone of England and Germany. The only two genera which have yet been found in our rocks differ somewhat from each other also in the degree of heterocercal structure which they present; those species which, following Professor Agassiz, in *P. fultus*, I have allotted to the genus *Palæoniscus*, having the heterocercal structure more decided. But even in these, the tail has a different aspect from the *Palæonisci* of Europe. In the latter, the upper lobe of the tail seems hardly to partake of the character of a fin, and the lower lobe appears to be only a finlike appendage of the upper, like a second anal fin, while the scales, and no doubt the vertebræ, extend to the extreme point of the upper lobe."

"The other genus, the *Catopterus* of our rocks, exhibits the heterocercal structure in a still more modified degree. So nearly does it approach in this respect some genera classed as homocercal fishes, such as *Semionotus* and *Pholidophorus*, that in an early memoir published in the Annals of the Lyceum of Natural History, Vol. VI., I was led to rank it in that division, subject to a qualifying note. Its relations are, however, rather to the heterocercal fishes, or, perhaps, to an intermediate group.

"This point is an important one in its bearing upon geological questions, for it is now well ascertained that the true heterocercal tail [in the Lepidoids] is peculiar to the palæozoic, and lower mesozoic rocks, no fish of that character having been found higher in the series than the triassic rocks, while the true [strict] homocercal tail does not occur

below the lias. When, therefore, we find in the fishes of our sandstone rocks, a structure which seems to be intermediate between the true homocercal and the heterocercal divisions of Agassiz, the conclusion seems irresistible, that the including rock *cannot be older* than the triassic, while it must be placed *at least as low* in the series as the lias or oolite."— *Report*, pp. 5, 6.

"Only four species of the genus *Catopterus* are yet known; three of which are found in the red sandstone of New England and New Jersey, and the fourth in the coal rocks of Eastern Virginia."*— *Report*, p. 7.

His descriptions of these four species of Catopterus are found in the Report, and were then prior to any known notice or description of these fishes, other than our own. These descriptions, together with those of the more numerous species of the genus *Ischypterus*, are yet withheld from publication, on account of the contemplated arrangements for completing a monograph of the fishes of this formation in the United States.

I have thus shown the examinations and conclusions of Mr. J. H. Redfield on these fishes, as first published in 1837, and as found in his Report to the American Association, in 1845. In the first of these, he points out the age of the containing rocks, and within the same limits that now appear to result from all the subsequent researches.

At the meeting of this Association held in Cincinnati, in April, 1851, the present writer made a communication on the Post-Permian character of the Red Sandstone rocks of Connecticut and New Jersey, as shown by various fossils. I then exhibited, together with two species of *Voltzia*, some specimens of the genus Catopterus from these rocks, showing the homology of their caudal structure with that of the *Catopterus macrurus* from the coal rocks of Eastern Virginia. This was induced in part by the fact that Sir Philip Egerton, in a paper of Sir Charles Lyell, in the third volume of the Journal of the Geological Society, had separated this Virginia species from its congeners in the New Jersey and Connecticut rocks, on the ground that the former belonged to the homocercal, and the latter to the heterocercal divisions of Professor Agassiz.†

* Others have since been obtained.

† Sir Charles Lyell *On the Structure and Probable Age of the Coal-Fields of the James River, near Richmond, Virginia.* Journal of the Geological Society, Vol. III, 1847, from pages 275 to 278.

Previous, however, to this publication of Sir Charles, repeated and careful examinations, with Professor Agassiz, of the numerous species of Catopterus in my possession, collected from the localities of the three different States, had appeared to establish fully their similarity, in respect to the caudal structure. Also, that the *Catopteri* of all the localities, including Virginia, might continue to be referred to the *homocerci*, as in the case of some European genera, or that, more properly both they and the other fishes of these rocks, might be referred to a distinct and intermediate division, which is *sub*-heterocercal in its character, if I may so speak. I, therefore, reclaim the *Dictyopyge* of Sir Philip Egerton, founded on my species, *C. macrurus*, as still belonging to the genus *Catopterus*. I refer to this matter on the present occasion on account of the important relation which it has to the geological age of these fishes, as found in the several States.

I may add in further explanation, that Sir Charles Lyell, in the paper referred to, states that "the genus Catopterus was instituted by Mr. Redfield for certain species of heterocercal fish from the Connecticut red sandstone." He seems not to have noticed that the genus was instituted by Mr. J. H. Redfield, in 1836, for a *homocercal* fish, according to the analogies afforded in the *Poissons Fossiles* of Agassiz; and he probably alluded only to my own later notices in Silliman's Journal, 1841, Vol. XLI. p. 27. All the fishes obtained by him from the sandstone of the Connecticut River are also pronounced heterocercal, while the Virginia fish is stated to be homocercal; and this is supported by the opinions of Professor Agassiz, as given on first seeing specimens of these fishes in Europe. Based on this designation, Sir Philip Egerton proposed his new genus *Dictyopyge* for the *C. macrurus* of the Virginia rocks.

In regard to the other fishes of New England and New Jersey, Mr. J. H. R. had reluctantly followed the work of Professor Agassiz in assigning them to the genus *Palæoniscus*, although this eminent naturalist had then only seen two imperfect specimens; but Mr. R. then alluded to their structural affinity with the liassic fishes, as we have seen in his concluding paragraph already quoted, and impliedly in the descriptive portion of his paper. In my own notices, of 1841, referred to above, I suggested that their less heterocercal form, and the peculiar structure of their fins warrant their being placed in a separate genus. Sir Philip Egerton recognizes the division, as did Professor

Agassiz in 1846, and Sir Philip proposes for the new genus the name *Ischypterus*.

The question to which of the divisions of Agassiz, the Catopterus of Connecticut, and this fish of Virginia belong, is simply one of degree. Even if we were to admit a slight difference in this case, it could hardly imply the wide separation which has been claimed. Such a marked division founded on the structure of the tail cannot depend on the use of a term, however authorized, and must be decided by the fishes themselves.

In regard to this point of distinction, may I not quote the matured views of Sir Philip Egerton, so well expressed in the Journal of the Geological Society, 1854, p. 368: "Although this character, derived from the organization of the caudal fin, is one of great value and significance in the determination of various genera of fossil fishes; it is, nevertheless, necessary, in drawing general conclusions, to be careful not to assign to it more importance than it is strictly entitled to; for we find, by the comparison of several genera, that it is not one of those well-defined trenchant characters which can be affirmed to exist or not, as the case may be, but that it is variable in amount, passing from extreme *heterocercy* to absolute *homocercy* by a sliding-scale so gradual, that it is (at all events in fossil examples) most difficult to define a positive line of demarcation between the two forms."

As the terms have hitherto been used, such line of demarcation, if it exist, appears best indicated at the division between the palæozoic and the mesozoic strata; and perhaps in lesser degree, at the close of the triassic period.

In all our *Catopteri* the scales of the caudal base terminate near the middle rays of the upper lobe, "and not on the upper margin as in a true heterocerque tail."* Good figures by Dinkel of the species *C. macrurus* of Virginia are given in the above-mentioned paper of Sir Charles Lyell.

It has been seen that Mr. J. H. Redfield considers the other fishes of the Connecticut River and New Jersey rocks as more heterocercal in degree than the Catopterus. In some of the species, however, this difference seems less obvious after a close examination of the structure, than it appears at first view. One or two of the species in my possession, I think, are even more nearly homocercal than the Virginia fish.

* See Egerton as last quoted, page 370.

I desire to add, that two of the *Lepidoti* from the table-land of India, of which figures are given in the Journal of the Geological Society, show very strong resemblances to two or three of my fishes from the sandstone of Connecticut River at Sunderland, to one of which I had proposed the name *Ischypterus Marshii*. Is it not probable that the vast extent of sandstone and trap in that distant region is of like age with our Newark group?

Already I have ventured to state verbally to the Association, that in the valuable collection of fossils from the coal-field of Deep River, in North Carolina, now exhibited by Professor Emmons, I have recognized several well-characterized fragments of the genus Catopterus. A close comparison of these with specimens in my cabinet may, perhaps, show a difference of species. But my present impression is that of identity with one of the New Jersey species.

It would be premature to conjecture how far the new fossils of Professor Emmons may affect the question of the relative age of these rocks. But when we consider that these fishes evidently belong to fresh-water or estuary deposits, as is shown by the entire absence of any remains of large marine fishes, by an almost equal absence of shells, and by the numerous fossilized fragments of terrestrial vegetation with which the fishes are associated, the chronological evidence afforded by their characteristic organization would seem to be more determinate than that of saurians, plants, or marine fishes, whose general habitat and power of distribution enable them to occupy a greater range in the geological series.

P. S. It is proper to add, that having now compared the remains of Catopterus of Professor Emmons' collection with my own specimens of the genus, I find them scarcely distinguishable from most of those of the New Jersey and Connecticut rocks. Indeed, they appear to be identical with *C. gracilis*. The chief differences appear in the larger size of most of the Carolina specimens, which may be due to conditions more favorable to their growth, and in the less flattened condition of the basal portion of the strong and elongate front ray of the pectoral fin, — owing, probably, to a nearly equal pressure on all sides in the carbonaceous paste or sediment in which they were fossilized.

New York, September 12, 1856.

7. On the Occurrence of Fish Remains in the Carboniferous Limestone of Illinois. By A. H. Worthen, of Warsaw, Illinois.

The occurrence, in a fossil state, of the remains of fishes in the mountain limestones of the Western States, has, up to the present time, been regarded as extremely rare, and, if we except the thin bands of limestone about to be described, these remains are among the rarest organic forms that meet the eye of the collector in his researches among the several beds that compose the sub-carboniferous or mountain limestone series of the region under consideration.

Several years since, while engaged in collecting the fossils of this formation in the vicinity of Warsaw, Ill., a thin band of gray crinoidal limestone was observed, which contained the palatial bones of fish in considerable abundance, and subsequent research has revealed two more of these "*platforms of death*," lower down in the series, densely filled with these remains. The subjoined section gives the relative thickness and succession of the series in this vicinity, and also shows the position of the fish beds.

The upper fish bed is situated in the upper part of what I shall call, for the want of a better name, the Lower Archimides Limestone, inasmuch as it is the lowest bed at present known to contain fossil corals of the genus Archimedes.* The remains from this bed, with one or two exceptions, consist entirely of palate teeth associated with Cyathophylla-formed corals, Spirifer Oralis, and Spirifer Cuspidatus. The middle fish bed is situated at the base of this Archimedes limestone, and near its junction, with the cherty beds below. This bed has proved by far the most prolific in these remains, and from it I have obtained more than five hundred well preserved teeth at a single locality and on a surface not exceeding ten feet square. The fossils from this bed are mostly jaw teeth with comparatively few palate teeth and spines.

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* A peculiar form of Fenestella. See a description of species in this volume.

The matrix in which they are imbedded is a coarsely granular crinoidal limestone not exceeding four inches in thickness, and sometimes so friable as to be easily crumbled between the fingers. This character of the matrix enables the collector to obtain these delicate and beautiful fossils in a rare state of preservation. In addition to the Cyathophylla-formed corals mentioned above, as occurring in the upper bed, we have in this an interesting coralline form, occurring in equal abundance and belonging to a genus with which I am unacquainted. I have also obtained the head of one species of Actinocrinus from this strata. This bed is separated from the one above by the limestones and marlites of the Keokuk quarries, from twenty-five to thirty feet in thickness.

The lower fish bed is situated near the top of the Burlington crinoidal limestone, and the strata in which the fish remains occur do not differ materially, either in their lithological or paleontological character, from the associated strata. This crinoidal limestone forms the base of the mountain limestone series in this region, and rests directly upon rocks equivalent to the Portage and Chemung groups of New York.

This lower bed has yielded a great number of teeth, though they are usually of smaller size than in the upper beds. This stratum was first observed at Quincy, Ill., and subsequently has been recognized in Henderson county, in the same State, and at Augusta, in Iowa, points nearly one hundred miles distant from the one first named, showing, as I think, that these fish beds are not local, but retain their peculiar fossiliferous character over a considerable geographical extent of territory. In addition to the fine teeth and spines which have been obtained from this bed, it has also afforded one well-marked bone nearly four inches long.

From the specimens before us, it would seem that the fishes of the sub-carboniferous era increased in size from the commencement to the end of that period, and that by far the greater portion of them were cartilaginous, only two well-marked bones having been obtained among at least one thousand well-preserved teeth.

The Pentremital and Archimedes limestones of southern Illinois, which form so striking a feature in the geology of that region, and which properly overlie those in this section, wedging out in a north-

erly direction, and entirely disappearing before reaching the mouth of the Illinois River, have afforded us several very fine specimens of fish remains; but a very careful examination has not yet revealed any strata in which they occur in such profusion as in the lower beds.

In the more southern extension of this formation, through Tennessee and North Alabama, notwithstanding the greatly increased thickness of these beds, attaining, as they do, in the valley of the Tennessee River, a maximum of more than one thousand feet, these remains are exceedingly rare, and a careful research of several days during the past winter yielded only three or four specimens of this class of fossils.

An interesting inquiry suggests itself as to the causes which led to the destruction of such great numbers of the vertebrated inhabitants of the ocean during the deposit of the thin bands of limestone in which their remains are entombed in such profusion. Unlike the ichthyolites of the old red sandstone below, and the lias and chalk above, those of the mountain limestone now before us, only occur in the fragmentary condition of isolated teeth and spines, affording in themselves no clue to the causes which may have operated in their destruction, and leaving us to conjecture whether they fell victims to the ravages of disease, or were destroyed by the sudden injection of heated water or noxious gases into the ocean which they inhabited.

For the want of the necessary authorities on this branch of paleontology, and having had no opportunity of comparing our specimens with those already described from European localities, we have not attempted to determine how many of our fossils can be identified with European species. Nevertheless, we may reasonably expect, that when our collections from the mountain limestone and coal-measures of the Mississippi Valley come to be fully collated and determined, many new species will be added to those already known to occur in the upper paleozoic series.

Section of the Sub-Carboniferous or Mountain Limestone Series exposed in the River Bluffs in Adams and Hancock Counties, Illinois, showing the position of the Fish Beds.

	Thickness.		
			Coal Measures.
	25 feet.		Concretionary and Brecciated Limestone.
	30 feet.		Arenaceous Limestones and Marly Clays with Archimedes.
	10 feet.		Magnesian bed.
	45 feet.		Geode bed.
Upper Fish beds.	40 feet.		Lower Archimedes Limestone.
Middle Fish beds.	70 feet.		Cherty beds.
			Quincy and Burlington.
Lower Fish beds.	100 feet.		Crinoidal Limestone.

III. ZOÖLOGY.

1. On the Names of Animals and Plants, with Reference to the Origin of Languages, and to the Countries where Nations passed their Childhood. By Dr. David F. Weinland, of Cambridge, Mass.

Every European naturalist, who comes to North America, must be struck with the fact, that the Anglo Saxon race, which has had possession of this continent for three centuries, has not formed *new* names for the *new* animals and plants of the country; but — with the exception of some artificial and some Indian names — has applied and still uses throughout, old English names for the American animals, though the latter are nearly all quite different from those animals to which the names originally belonged. Such names are, for instance, Bear, Badger, Catamount, Mole, Deer, Chamois, Buffalo, Rabbit, Porcupine, Robin, Quail, Grouse, Cuckoo, Goatsucker, Jay, Shrike, Starling, Linnet, Goldfinch, Wren, Sparrow, Pigeon, Turtledove, Coot, Rail, Godwit, Bittern, Widgeon, Teal, Lizard, Adder, Toad, Treetoad, Salamander, Perch, Bass, Gurnard, Sculpin, Mackerel, Blenny, Barbel, Hake, Flounder, Sole, Eel, Lamprey, etc., all of which are applied in the American-English language, to animals specifically or even generally different from the European animals which they designate in England. Thus, for instance, Robin means in America, Turdus migratorias, a bird belonging to the thrush family, while in England it is used to designate Sylvia rubecula, which belongs to the warblers; the name Partridge means in England a bird belonging to the Perdicid, (Quails, etc.), in America a Tetraonoid.

Starting from this fact, we have been naturally led to consider the names of animals in other languages, and we have been surprised, that in all those to which we have referred which belong to the Teutonic, the Pelasgic, and Semitic stock, we find the same fact, namely, that every nation has, only for the animals and plants of its native country, real roots of words, which express one typical kind of animals or plants and nothing else; and that no nation has a peculiar true name for any

foreign animal or plant, but that it either applies to these names of its native animals, or it borrows the names from another nation; or uses comparing, artificial names, like Guinea-pig (German: Merschweinchen), Camelopard, Nile-horse (Greek: Hippopotamus, German: Nilpferd), Sea-horse (German: Walross), etc. How names are borrowed by different languages we see particularly in the most striking representatives of the animal kingdom. The name lion in German; löwe, leu, in Old German; lewo, in Anglo-Saxon, lio; leon, in Dutch; leeu, leeuw, in Swedish; leion, in Danish; loeve, in Icelandic; leo, lion, in Polish; lew, in Bohemian; leo, in Latin; in the Romanic languages, (French, Spanish, and Portuguese,) lion is a Greek root-word, λέων (leon). The Semitic languages have other roots for the same animal; in Hebrew arí means the male, labi the female, and gur the young. Now we know that the lion is a native of Greece; that it has lived within historic times in Macedonia, therefore, it has a true name in the Greek language; we know further, that it now lives all over that part of Asia and Africa which seems to be the cradle of the Semitic nations, namely, in Syria, Arabia, and Egypt, therefore the Semitic nations have another true name for it; and, further, they have three such names for the different sexes and ages; we know, too, that the lion never lived in Central, or Northern, or Western Europe, therefore neither the Teutonic nor Sclavonic languages have true names of their own for this typical animal; they have borrowed the name from the Greek, the nearest nation which had the lion native. The tiger, an animal as typical as the lion, has no original name in any European language, nor has it in the Hebrew, for the tiger is not (as stated in some dictionaries) from a Hebrew, but from a Persian root. Now this agrees again exactly with the geographical distribution of the animal. Though it lives all through the middle of Asia from Hindostan to Siberia; it does not live in Syria nor in Egypt, therefore it has no name in the Semitic language. Moreover, it does not occur in Europe, therefore it has no name in the Palasgic, or Teutonic, or Celtic. All these nations have borrowed the name from that Persian root. The elephant is another striking example. Its name is from either a southern or south-western Asiatic root, or it is borrowed from the Hebrew äleph, which means an ox. The elephant is an inhabitant of southern Asia, and if the name is really of Hebrew origin, it shows that the Hebrews compared it with their own, because the elephant never lived

in the native country of the Semitic nations, and they, therefore, have no true name for it. Another example is the name camel. This has a Semitic root, in Hebrew it is Gämäl. The animal is a native of the Semitic country, and, therefore, it has there a true name, while all European languages have borrowed the name from the Semitic, because the camel never lived wild in Europe. In order to be rightly understood we must notice here a mistake, which we see sometimes made by philologists. The fact that the name of an animal or a plant is common to two or three or more different languages, is often used to prove that those languages have some affinity to each other. The names elephant, tiger, and camel, are common to the Pelasgic, Teutonic, and Celtic languages. Does that show any affinity between these languages? To us it shows nothing else than that all these different nations have taken the name with the thing from that nation which first had it. If, as has been stated, the name cow is common to the languages of all those nations which have cows, this shows to us not an affinity of the languages, but only that the cow lived wild in the native country of one single nation, and that hence it has been carried to other nations, and its name with it. But sometimes nations really seem to make new names for foreign animals, either because they do not know the names used in the country where the animal originates, or because, perhaps, that name has too strange a sound. But what are the names thus made! They never are true new names, they are mostly artificial, comparing names, such as Nile-horse, or hippopotamus, for that heavy pachyderm of Africa, which has hardly any resemblance to a horse, or Guinea-pig for that little knowing animal from Brazil, or camelopard, also, as the ancients called the Giraffe, comparing it to a camel and to a panther; or Sea-cat as the Germans call the long-tail monkeys, because they saw them coming over the sea, and compared them with cats; or earth-apples, as in some parts of Germany the potatoes are called, etc. These examples show how much nations strive to reduce the names of all foreign animals and plants to those of such as are native with them, and they often even go so far in this as to apply the names of their native animals and plants to foreign ones which are entirely different. This has been done to a great extent by the Anglo-Saxons, as they have come over from England to North America.*

* See the names mentioned above, robin, etc.

Now if this be true, if nations have only true names for the animals which inhabit their own country; moreover, if it be true, as all philologists believe, that a nation can originate root words only in its childhood, while forming its language, we can draw the important conclusion, that *wherever we find a nation which has true names for all the typical animals and plants of a certain country, that country is the seat of its childhood.*

Thus zoölogy and botany and philology combined, may help ethnography in determining the cradles of the nations of the earth. We purposely say the cradles, not the birthplaces, because our arguments do not reach farther back than to the childhood, that is, the time in which a nation forms its language by originating root words.

Now is this principle a practical help in our investigations? We have tried it with language with which we are best acquainted, the German, and have found the remarkable fact, that the high German language, which has a true name not only for all the typical mammalia, birds and reptiles, (but also for all the different fresh-water fishes of southern Germany,) has not any true name for the most characteristic mammalia, birds and fishes of those very seas which border upon lower Germany. All these animals have only comparing names, such as Seehund (sea-dog) for seal, Seeschwein (sea-hog) for dolphin, Seeigel (sea-urchin) for the echinus, Seestern (sea-star) for the star-fish, Seeteufel (sea-devil) for Lophius, Seenadel (sea-needle) for the Syngnathus or needle fish, etc. This fact seems to me to show, that the High German language is the language of a continental nation which lived its childhood in southern Germany. How far this is true for the Low German and the Anglo-Saxon, we are at a loss to say. They seem to have many true names for the sea animals, such as seal, and many others; but the question arises, then, whether they have not taken those names from a nation which lived upon those sea-shores before they came there. This question must arise because there are still so many typical sea animals for which they use only comparing names. But we have no doubt, that the Laplander has true names for all his sea animals.

We see from these considerations what value there would be in a critical catalogue of the names of animals and plants which would indicate exactly the kind of animals or plants meant by a given name, and also tell the geographical distribution of each. Such a dictionary

might also be of philological value in relation to the origin of many verbs. In running through a Hebrew dictionary for names of animals and plants, we found that the author (Simonis) tried to carry back every name to a verb; thus he derives anaphah, the heron, from anaph, to be in wrath; athon from athan, to walk away slowly; cariack, serpent, from carack, to fly away quickly; and in the same manner we find such names treated in dictionaries of other languages. Now we may justly ask; — Which is the more natural, that men, in the state of nature, first make verbs and then derive from them the names of the animals, or that they first name the animals which live around them, by a certain sound, and afterwards derive a verb from that sound, a verb which expresses very naturally the most striking character of that animal? We deem the latter process the more natural. Thus we might rather derive carack, "to fly quick away," from cariack, the serpent, than inversely. We have no doubt that, at least in Hebrew, many verbs are still to be recognized as derived from names of animals.

I have begun to collect materials for a catalogue of the names of animals and plants, as spoken of above; and I shall be glad to receive information and contributions from all those who are interested in the subject. When the work is published, the name of the contributor will be given as authority for the statement.

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2. On the Digestive Apparatus of the Acanthocephala. By Dr. David F. Weinland, of Cambridge, Mass.

The anatomy of a worm would seem perhaps to many, a matter of not very great importance. But those who have followed the development of science know that correct observations made upon the so-called lower animals, are often the starting points for the most beautiful generalizations, and afford the most simple, and therefore the broadest, basis for the physiological understanding of animal life. For in these lower animals, in a worm, for instance, we have all the physiological systems, the reproductory as well as the digestive and respiratory or-

gans in the simplest form, and we can see them all acting together in one field of the microscope.

Some years since a remarkable discovery (the penetration of the Spermatozoa into the egg), was made on an intestinal worm, and now this fact has become a law extending very likely throughout the animal kingdom. This, I think, is the true view of the so-called lower animals and of the study of their organization.

In spite of the labors of centuries, there still remains a large number of animals which are said to have no distinct digestive apparatus. And this is certainly true of the microscopic Rhizopodes, an order of Infusoria, which may rightly be called Protozoa, since we have not yet been able to bring them under the head of either of the four great branches of the animal kingdom. These Rhizopodes feed, as my friend Edward Claparède, of Berlin, discovered some years ago, by throwing all their body over their prey, (generally another Infusorium,) which then at once appears in the midst of the body of the Rhizopod and is some minutes after a shapeless ball of food. Now these Rhizopods really consist of nothing but a viscous mass of the most variable form, without a membrane around the body, but with a heart, if we may call such a roundish, reddish dot, pulsating at fixed intervals, from which the intestine fluid seems to start.

We see here the lowest form of animal life, and in looking at such a simple development of all the physiological organization, we are not at all astonished to find no distinct intestine. It is equally true that such an intestine does not exist among many of the Radiata, the Polypi, for instance; and now there are said to be even among Articulata, some animals which are destitute of a distinct digestive apparatus. Thus among Helminthes or intestinal worms, no mouth or intestine has yet been found, either in the group of Cestoda (tape-worms), or that of the Acanthocephala or Echinorhynchi. These worms are said to feed by imbibition through the skin. Of the Acanthocephala, a large species of which is very common in the intestine of the hog, Dujardin, in 1845, says: "Animaux sans bouche et sans tube digestive; se nourrissant par absorption."* *Blanchard*, in 1848, who succeeded in injecting the circulatory apparatus of many Helminthes, says of these

* See Histoire Naturelle des Helminthes, p. 483.

worms: "Point d' ouverture buccale, point de tube digestif."* *C. T. von Siebold*, in 1848, says: "Bei den Echinorhynchen wird höchst wahrscheinlich die Zufuhr von Nahrungsstoffen vermittelst der Einsaugungskraft der Hautbedeckung vermittelt."† *Diesing*, in his Systema Helminthum Vindobonæ, 1851, Vol. II. p. 18, says: "Os in proboscidis apice; Tractus intestinalis proprius nullus." Thus all these helminthologists agree in this, that there is in Acanthocephala no intestinal canal; though Diesing, in opposition to the others, speaks of a mouth on the top of the proboscis, which, however, as Siebold has already observed, and as we can fully confirm, is a mistake, there being but a pit in that place, and no opening at all.

I hope to throw in the following observations some light upon this subject, namely, to show that there exists in Acanthocephala a real nutritive system which takes up food from outside, consisting of two rather long stomachs hanging down from the head into the cavity of the body, starting from two mouth-openings near the basis of the so-called neck. I will add that I have succeeded in showing the existence of this digestive apparatus to Professor Louis Agassiz, in the living animal, to his full satisfaction.

Last winter, in studying the anatomy of the North American turtles for the first volume of the work of Prof. Agassiz, I had the rare chance of dissecting many fresh specimens of these reptiles. I directed my attention particularly also to their parasites, which until now have been but little studied. In the small intestine of Emysserrata, I met in all specimens I dissected (more than a dozen) a Nematoid, the Cucullanus microcephalus Rud, and an Acanthocephal, a new species of Echinorhynchus, both, but particularly the former, in large numbers. In this Echinorhynchus I not only recognized at the first sight the distinct stomachs, as described above, but also, at least in some specimens, the two mouth-openings. In all the specimens which I observed more closely, (about fifty,) the stomachs were filled with a brownish granular matter. The brown granules which they contain are irregular and float in a transparent fluid, and I sometimes succeeded in pressing this food out through a mouth-opening by a slight pressure of the covering-glass. But the structure of these stomachs is very curious; they are

* See Recherches sur l' Organisation des Vers, p. 283.

† See Lehrbuch der Vergleichenden Anatomie der Wirbellosen Thiere, p. 128.

not simple sacs, but contain, or rather are built up of a network of fine tubes, with a central tube in the midst, from which the finer ones start. Again, these finer tubes are connected in the neighborhood of the mouth-openings with the extensive vascular system of the walls of the body. On the transit between the tubes of the stomach and the vessels of the walls of the body, I saw a valve which opened periodically, and I watched once for a good while the process of floating from the tubes of the stomach into these vessels.

Thus we think the digestive process of Acanthocephala — for very likely the same is the case in the whole order — is this: The two mouth-openings receive the food and lead into the tubular system of the stomachs, which at the same time serve as digestive glands. We may compare them with the appendices pyloricæ of some fishes, the Salmonids, for instance. From these stomachs the digested food is led into the vascular system of the walls of the body.

The Echinorhynchus of Emys serrata, upon which these observations are made, when fresh and without exposure to water, and placed under the microscope, is very transparent. Still the mouth-openings are generally not to be distinguished, but whenever I saw them, they were wide open. They were still larger in another Echinorhynchus, which I met with in Lophius piscatorius.

Though from the statements of helminthologists, as quoted above, it might seem that they have not noticed this extensive apparatus; still this is by no means the case. On the contrary, the two stomachs were described long ago, and very accurately, particularly by Siebold, l. c. p. 134, under the old name of Lemnisci. Siebold describes them under the organs of circulation, because he unluckily did not see the two mouth-openings. But even these were seen by Mehlis, but as nobody until now has seen them since, their existence has been denied. The supposition of Blanchard, that the proboscis with its bag is at least in the younger state of the worm, a kind of intestine, the mouth-opening of which is soon obliterated, is evidently a mistake. The whole mechanism of the apparatus for stretching out the proboscis, which is exactly the same as in Cestoda, and which can be studied most beautifully in Tetrarhynchus, forbids this supposition.

But there might still be left some doubt at least about the name of this digestive apparatus, as we have described it above. There are, strangely enough, two mouth-openings; and the structure of the stom-

ach is very similar to that of a gland. But if we call digestive apparatus those organs which lead the food from outside into the animal through certain openings, and which digests that food and passes it over into the circulatory system, we are justified in calling so the above-described system of Echinorhynchus.

IV. PHILOLOGY AND ETHNOLOGY.

1. On the Relations between Chinese and the Indo-European Languages. By S. S. Haldeman, of Columbia, Pa.

§ 1. The form of Chinese is so different from that of Latin or Greek, that we might readily consider as fallacious all attempts to exhibit an identity of words between them.

§ 2. Some have endeavored to establish such an identity upon certain words of like form and meaning, which cannot be depended upon, being frequently the result of accident, like the English *bank* (of earth) and Mandingo *banko*, with the same meaning; the English *shave* when compared with the Eskimo *shavie*, a knife, and the Brazilian *ara* with "air," and *co* with "go." Similarly, the Kaffer *le*, *lo*, for "that," corresponds with Fr. le, Ital. lo; the Betjuana *ké* is near to the Germanic "*ik*" and Latin ego; and the Bushman *ăe* to the English *I*.

§ 3. Resemblances like the following, between Chinese, English, etc., should be admitted with extreme caution, as likely to be accidental: gnaé, *to gnaw;* sëuk, sugo, *to suck;* báy, *to buy;* wân, *white*; wan, *crooked* (wend, wind); tam, *damp;* tan, *a red color;* tàp, *to reiterate;* lók, *to leak;* t'hek, *a house* (tectum); lap, *loose skin;* t'hew, *a thread* (thew); t'hong, *a thread, a line* (thong); kap, *to collect together*, (keep, capio); kap, *a cape;* kat, *to cut;* etc.

§ 4. From the paucity of Chinese words, many of them are overburdened with meanings, which gives room for accidental resemblances. Thus there are fifty different characters read "sun," and of some of these the meanings are very diverse, one meaning *believe* and *real*, another *thick* and *liberal;* but none of these meanings agrees with the English *sun* or *son*. Of twenty Chinese words, *sit* (meaning to eat, to

lose, to know, to rub, a rule, etc.), the nearest to English is that meaning a residence, often called a *seat*. This resembles the language of a child who would use essentially the same word for stick, cake, did, toad, dog, duck, scratch.

§ 5. From the monosyllabic nature of Chinese, and the necessity of placing a vowel between most consonants, the words are very different from those of Latin. Thus the word Batavia has been cut down to pa, and cap, *a ship*, stands for the Malay capal; Welsh ceubal, *a ferry-boat;* Gaelic cabaile, *a navy;* Gr. *Κύμβη, a boat,* σ-*Καφος, a skiff;* Heb. Qŭ'B, *a concave vessel;* Arab. CūB, *a cup,* CaV*θ*al, *a ship.*

§ 6. We must, therefore, in comparing Latin with Chinese, reduce it to its roots, reject the prefixes con-, sub-, post-, ex-, cr-, str-, etc., before consonants, and reduce them to a single consonant before vowels, and replace the useful and enlivening *r*, with *l* or *s*. Under this dissection, ICTUS, a blow; PRECOR, I pray; ROGO, I ask; and STRIX, (Persian, tshōkak) an owl, might become respectively ic, lec, sec, tec; which, from the want of the Latin inflecting material, might each have the power of from ten to fifty words, as distinct as RINGOR, I gape; SECO, I cut; and PLICO, I fold. But as STRIX, to be pronounceable, must become something like satalicasa, its Chinese form might be *sa*, as Batavia is *pa*.

§ 7. Similar imitative words may occur in languages the most distinct, without indicating linguistic affinity; as in the names of animals which imitate their cry, like the Chinese beâou, a cat, the voice of which is called miau by the Germans, *m* being a nasal *b*. But an identity of imitative words is not common between languages of different stocks, because they are submitted to the local laws of speech. In English, one who hesitates what to say, is said to *hem and haw*, although he does not use one of the sounds imitated in this translation into speech; whilst the French imitative word *siffler* is different from the English *whistle*, *hiss*, and *whiz*, although the root sif- is a metathesis and permutation of *whiz*, *fiz*. The English imitatives *roar*, *rush*, however natural they appear, need not be looked for in Chinese; nor will Cherokee (in which *p*, *b*, *f*, *v*, are wanting) furnish phonetic equivalents to pop, bob, bubble (*πομφός*), and their cognates in viv-id, vi-olent, vi-gor, *Βί-ος*, *Βί-α*, be, VI-R, VI-REO, VI-S, etc.

§ 8. But whilst imitatives must be compared with caution, if we find that an imitative basis has been not only adopted, but modified (as

far as the genius of different languages would permit) in the same manner, with the same prefixes, having the same power, we will have gone far to prove a common origin in the languages where such a uniformity occurs, — especially between Chinese and the European languages, where the differences are so obvious.

§ 9. In the present essay, a throat exclamation will be traced into European speech, together with its ramifications and growth by means of reduplication, metathesis, and the use of prefixes; to be followed by their Chinese equivalents. Throat sounds are used in various languages, to form words for cough, throat, speech, wailing, cricket, gurgle, emotion, rigid, narrow, action, work, break, noise, pound, fragment, breach, crack, point, thorn, spear, axe, molest, strike, tear, throw, shoot, ray, light, torch, fire, blow, go, extend, etc.

IRISH.

§ 10. Och, *oh, alas;* cohù, *sorrow;* ochàn, *a deep sigh;* t-achta, *choking;* g-ŭch, *a loud voice;* r-ŭch, *a running, a rushing;* sruch, *a flowing of waters, a stream;* scrìach, *a screech.*

WELSH.

§ 11. O, *alas, out of, what proceeds;* oi, *well! to proceed;* oc, *from, out of;* og, *what is full of motion or life, youth, a harrow;* (Latin occo, to harrow). The force of the Irish prefix *r-*, appears in Welsh as follows: —

§ 12.
rhu, *a loud utterance.*
rhw, *what breaks or grows out.*
rhuo, *to roar, to talk.*
rhueinell, *a clarion.*
rhe, *swift motion.*
rha, *what forces.*

§ 13.
uch, *what breaks out, a sigh.*
ig, *a hiccup, a sob.*
och, *alas;* ich, *a squeal.*
ochan, *a groan;* igio, *to sigh.*
achan, *a hymn.*
ag, *an opening, a cleft.*

§ 14. By combining rhu with uch, etc., and using prefixes (as c-, ys-, gw-,) to the compounds, we get the two following series: —

rh-ach, *what is forced out.*
rhoch, *a grunt, groan.*
rhinc, *a creak, gnash.*
rhing, *a creak.*
rhunc, *a snort, a rattle.*
rhych, *a trench.*
rhic, rhig, *a notch, groove.*

c-r-ech, *a scream.*
greg, *a cackle.*
grig, *a low rustle.*
gryg, *harshness, roughness.*
grwng, *a rumbling noise.*
ys-g-rech, *a screak.*
ysgrechog, *a jay.*

§ 15. The reduplication of ig, ich, (and the use of prefixes,) gives (*c* being *k*, as in Latin),

ceg, *the mouth, throat.*	cegu, *to glut.*	gwag, *a vacuum.*
cegio, *to choke.*	cyngan, *speech.*	ys-gecru, *to bicker.*
ceer, *a brawl.*	gw-ich, *a s-qu-eak.*	h-uch, *a sow.* (Pers. khōk, *a hog.*)
cecren, *to scold.*	gwica, *to cry wares.*	p-uch, *a sigh, a grunt.*
cocr, *coaxing.*	gwach, *a hole.*	p-ucho, *to sigh, pant, grunt.*

Compare Angl. cegan, *to call* The p- of p-uch occurs in (de)p-rive, p-lacid, etc.

§ 16. The Welsh root-word lla (akin to rha, § 12,) is a noun meaning, that which *breaks out*, is light, or *clear*. It has various cognates, as llae, *an expanse;* lli, *a flood;* llw, *an exclamation, oath;* llewer, *light;* lloer, *the moon;* llewen, *a focus;* llewyrn, *a meteor;* llwys, *clear, pure, holy;* and with a prefix, g-lwys, *pure, holy, fair;* g-law, *brightness;* golwch, *worship.*

§ 17. By combining lla and uch, we get the series, —

llach, *a ray, a slap.*	llwg, *what is bright.*
llachar, *gleaming.*	llugan, *a glitter.*
lluch, *a throw, a glance.*	llugas, *a dawning.*
lluched, *lightning.*	llugorn, *a trumpet.*
llig, *what shoots.*	llygad, *eye-sight, eye.*
llug, *a gleam.*	llygas, *splendor.*

§ 18. By combining lla and uch, commencing with the guttural, we get another Welsh series, —

gal, *spread out, clear.*	colon, *a peak.*	gawl, *a dawn, holy.*
galw, *to call, invoke.*	gall, *energy.*	geli, *a shooting out.*
galaru, *to lament.*	gallus, *powerful.*	gelin, *a sprig.*
col, cor, *a point.*	golau, *light.*	goliw, *a faint tint.*
col-p, *a dart.*	gole, *splendor.*	claer, eglur, *clear.*

The -p in col-p (Swedish, kol-p, *a dart*) is present in the English gulp, yelp, scalp. The following are Gaelic: —

gal, *weeping.*	geal, *fair, bright.*	gaol, *love.*
gul, *crying out.*	gilead, *whiteness.*	gealun, *fire.*
galan, *noise.*	galla, *brightness, beauty.*	gaoil, *boiling, anger.*

§ 19. The two preceding series (§ 17, 18,) suggest φ-λέγ-ω, to burn, shine, vex; φλέγμα, *fire*, (f-la-me): English, lo! look, light, call, yell, gul-let, clear, glory, glow: ἀΐ-γελλ-ω, *to announce;* ἀ-γάλλ-ω, *to make splendid, to exult:* Irish, găl, *white;* gălăch, *the moon:* Latin, LUCEO,

to shine; LUX, *light:* Gr. *λύκος, the sun; λύχνος, a lamp; γ-λαυκ-ὸς, blue, clear,* the L of which appears in *λάω, to look at; λεύω, to see, shine.*

§ 20. The same L (§ § 16, 19,) occurs in the Gaelic la, lo, laoi, *a day;* laom, *f-lame;* li, *color;* leas, *light;* leicc, leug, *a diamond, a gem;* lia, *a flood;* lua, *an oath, water;* lo, *water.* With these (and with rhu, § 12, *r* not being a Chinese element), we may compare the Chinese lê, *clear, bright, happiness;* lek, *bright, clear;* lōng, *fireworks;* lo, *a voice, a sound;* loé, *to converse;* lô, *a gong;* lō, *a drumming in the ear;* laóu, *a noise;* lêw, *a flood;* lē, *to flow rapidly.*

§ 21. From the continuousness of S, s-creak may have been intended for a continuous action: uch, ich, (§ 13,) being continuous, want the explosive sharpness that results from commencing with closed organs, a deficiency which c- (cay) would supply, besides simulating the closed glottis at the *beginning* of a c-ough, at the *end* of a hi-c(cup) during the *continuance* of ch-ok-ing or g-ag-ing, and the *frequentative* action of c-ac-ling, ch-uc-ling, and g-ig-ling.

§ 22. The root of s-c-r-eak is perceived in h-ic-cup, the enlivening *r* gives r-ing, (and the perversion r-ough): Latin, R-IC-TUS, the mouth; RAVCUS, hoarse, harsh; R-OG-O, to ask; Gr. *ῥ-έϝκ-ω*, to snort; *β-ῥ-ύχ-ω*, to howl; *κ-ῥ-ίζ-ω*, (fut. *κ-ῥ-ίξω*,) to c-r-eak; *κρίγη*, a creak, *κ-ῥ-άκ-της, κραγέτης*, a crier; Latin, C-R-OC-IO, to croak, leading by successive prefixes, to creak, cricket, crack, screak, screech, click, cluck, clang, etc.; Gr. *λ-ιγ-αίνω*, to cry out; *κ-λ-αϝγή*; Latin, CLANGOR; and gloc-io, to cluck. Starting with the root of ECHO, r- gives r-ixa contention, a t- prefixed (*τρίζω*, to stridulate, in the future tense) *τ-ῥ-ίξ-ω*, and an intensive s-, S-T-R-IX, an owl. This agglutination of prefixes shows a close affinity in the structure of Greek, Latin, and English words.

§ 23. GREEK.

[1] *ἠχή*, sound, clamor.
[2] *ἠχῶ*, echo.
[3] *εὐχή*, a prayer, boast.
[4] *ἀϝχω*, to throttle, torture.
[5] *ὀξὺς*, sharp, ac-id.
[6] *ἀκοή*, a sound, the ear.
[7] *ἀκούω*, to hear.
[8] *ἄχος*, affliction.
[9] *κωκύω*, to lament. (*ἰαῦ, οἰ*, alas.)
[10] *ὀϊζὺς*,↓ affliction.*
[11] *ἰ-αχ-έω*, to shout.

* The initial of this word is akin to the preceding. The mark ↓ indicates that the word is not a primitive form, *ζ* being probably derived from a guttural, like Sanscrit, Persian, and English *tsh*, which is rarely a primitive.

12 *αἰ-αγμα*, a sigh.
13 *ἰ-ωκ-ή*, din of battle.
14 *ὄχ-λος*, a mob.
15 *ἐγ-ὼ*, I, the sp-eak-er.
16 *ἐκεῖ*, there.
17 *ουκ, ουχ*, not.
18 *ὅ-γε*, this; HOC, *ge*, ye-s.
19 *ὀῖκ-άομαι*, I bray.
20 *ὄῖκος*, swelling, bulk.
21 *ὄῖκη*, size, a hook.
22 *ἐγ-είρω*, to arouse.
23 *ἄγε*, come out! hence to *egg*, or *agg* on.
24 *ἀΐ-γέλλ-ω*, to announce.
25 *ἀγάλλω*, to make splendid, to exult; *αἴγλη*, *αγλ-αΐα*, splendor.
26 *αὐγή*, light, the eye.
27 *φ-λέγ-μα*, fire, heat.
28 *ἄγη*, respect, envy, hate.
29 *ἀγαυρὸς*, proud, fierce.

*

30 *λ-άκ-ω*, to sound like breaking.[6]
31 *λέγω*, to speak.
32 *λακάζω*, to talk.
33 *λευκανία*, the throat.
34 *χ-λάζ-ω*,‡ to swell, be full, rush, gurgle.
35 *λιγαίνω*, to cry out.
36 *λίῖγω*, to hiss, whiz.
37 *λῖγνυς*, a smoky fire, smoke.[37]
38 *λ-ιγυ-ηχ-ὴς*, clear sounding.
39 *κ-λαῖγή*, clangor.
40 *λυῖγαίνω*, to sob, hiccup.
41 *φ-λάζ-ω*,‡ to stammer.
42 *ἄγω*, to b-r-eak.
43 *οἴγνυω*, to open.
44 *λ-ακ-έω*, to rend, break, resound.
45 *λακτίζω*, to kick.
46 *λάκτις*, a pestle.
47 *λίγδος*, *ἴγδος*, a mortar.
48 *π-ληγή*, a blow.
49 *π-λήκ-της*, a str-ik-er.
50 *λόῖχη*, a spear head, the tip of the t-ong-ue.
51 *λοιγὸς*, destruction.
52 *λειχήν*, lichen.†
53 *λάχνη*, wool.†
54 *λάκος*, a rag.[101] [102]
55 *τ-άγ-υρι*, a minute fragment.
56 *λάχος*, a lot, portion, appearance.
57 *λόχμη*, a bush, thicket.
58 *λυγαίος*, shady.
59 *λυγρὸς*, sad, weary.
60 *λύγη*, darkness.
61 *λύγος*, a shrub, an osier, flexible.
62 *λυγόω*, to bend, tie.
63 *λοξὸς*, oblique.
64 *τ-όξ-ον*, a bow.
65 *ἀγὴ*, a fracture,[42] a wave.
66 *ἀξίνη*, an axe.
67 *ὄγμος*, a furrow, track.
68 *ὄξετὸς*, a trench.
69 *ὀχὴ*, food, a hollow.
70 *ἀγαρικὸν*, a mushroom.
71 *ἀκάχω*, to molest.
72 *τρ-υχ-όω*, to harass.[4]
73 *αἰκ-ία*, injury.
74 *αἰγόδην*, impetuosity.
75 *ἴξαλος*, leaping.
76 *αἰξ*, *αἴγα*, a goat.
77 *ἀΐκαλὶς*, the arm.
78 *αἰχ-μὴ*, a spear point.
79 *μ-άχ-αιρα*, a sword.
80 *ἀκὴ*, a point.
81 *ἄκαν*, a thistle, brier.
82 *ἄκανθα*, a thorn.
83 *ἀκμὴ*, acme; *ακ-μαὶ*, pimples.
84 *ἔχις*, a viper.
85 *ἐχῖνος*, a hedgehog.
86 *ἀχρὰς*, the wild pear.
87 *στάχυς*, a sp-ike of corn, a plant, offspring.
88 *τέκος*, a child.
89 *στ-ιγ-εὶς*, an awl.
90 *τραχὺς*, rough, harsh.
91 *τριγμὸς*, a shrill cry.[119]
92 *δ-έχ-ομαι*, to tak-e, comprehend.
93 *μηχανὴ*, a work.
94 *δεκτὴρ*, a tak-er.
95 *δάκτυλος*, a finger.
96 *λιχανὸς*, the fore finger.
97 *λείχω*, to lick.[50]
98 *ὀρ-έγ-ω*, to stretch forth.
99 *τ-άγ-ω*, to grasp.[92]
100 *β-ραχ-ίων*, the arm.[98] [99]

‡

101 *βάγος*, *βάγος*, a rag.
102 *τ-ρῦχ-ος*, a tatter.
103 *β-ραχ-ὺς*, short, little, as if b-rok-en.

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* *λύα*, discord; *λα-*, *δα-*, *λε-*, are intensive, as in *λίαν*, *very*.

† From its broken appearance, — but *κ-ρέκ-ω*, is to *strike*, to *weave*; *κρόκη*, the woof; *κροκὶς*, nap, a lock of wool, threads sticking out of cloth; hence *κρόκος*, CROCUS, *saffron*, from the conspicuous stigmas.

‡ The force of R in No. [101], etc., (see § 12) is observed in *ὀρούω*, to rush upon; *ὄρω*, to move, excite, arise; *ῥέω*, to flow; *θ-ρόος*, uproar.

104 *ῥάκτος*, a steep rock.
105 *ῥακτήριος*, resounding, striking.
106 *ῥάχις*, the spine.
107 *ῥίζα*,↓ a root.
108 *ῥάχος*, a thorn bush.
109 *φ-ραγμών*, a thorn hedge.
110 *φ-ρακτήρ*, an inclosure.
111 *θ-ριΐκός*, a coping.
112 *τ-ειχέω*, to wall, fortify.
113 *τεκταίνω*, to construct.
114 *τεχνάω*, to make.
115 *ῥωγὰς*, split.
116 *σ-άγαρις*, a battle axe.[46]
117 *βράχω*, to crash, creak.
118 *βρύχω*, to howl.
119 *βόχθος*, a loud noise.
120 *ῥέΐκω*, to snort, snore.[91]
121 *ῥύΐχος*, a snout.
122 *ῥῆγμα*, a b-reak, c-rack.
123 *ῥηκτὸς*, broken.
124 *τ-ρ-ώγ-ω*, to chew.
125 *φ-αγ-εῖν*, to eat.
126 *φηγός*, the beech.
127 *τρύγη*, corn, pulse.[124]
128 *βόγος*, a granary.
129 *κρέκω*, to strike.
130 *τ-ράγ-ος*, a goat.
131 *κράκτης*, a crier.
132 *κ-ράζω*, ↓ to c-roak.
133 *κ-ρίζω*,↓ (fut. *κρίξω*) to c-reak.
134 *φ-ραζω*,↓ to relate.[41]
135 *φ-ρῖξ*, the murmur and rippling of waves.
136 *φρίκη*, a shuddering.
137 *φριξὸς*, bristled, rough, curly.
138 *θρίξ*, hair; [53] *note*.
139 *φρύγω*, to fry, parch.
140 *φρυκτεύω*, to kindle.
141 *αὔξω*, to aug-ment.
142 *πακτόω*, I make compact, *πηγὸς*, compact.
143 *πάγιος*, stiff with cold.
144 *πάγος*, frost, ice.
145 *πάχος*, thickness.
146 *παχύνω*, to render fat.
147 *πῆχυς*, the upper arm.
148 *πυγὼν*, a cubit.
149 *πυγή*, the haunch.
150 *πυκνόω*, I condense.
151 *πυκινὸς*, crowded.
152 *πυγμὴ*, the fist.
153 *πύκτης*, a b-ox-er.
154 *πηκτὶς*, a lyre.
155 *μαγάδις*, a lyre.
156 *μάχη*, f-igh-t.
157 *μέγας*, big.
158 *μακρὸς*, long.*
159 *μικρὸς*, small.*
160 *πόκος*, a fleece.
161 *πώγων*, a beard.
162 *πύξος*, the box-tree.†
163 *πεύκη*, the fir, a torch.†
164 *πίσσα*,↓ pitch, (*pixa?*)†
165 *πικρός*, pungent, bitter.

§ 24. LATIN.

The following numbers and words correspond, in a general way, with those of the preceding Greek series. Such a reference admits of much variation, a word in one language having affinities with several in another. To keep this in view [42] ICO, I strike, has the number of *ἄγω*, I break, and its derivative ICTUS, a blow, has that of *αἰκία*, an injury. The name of a singing-bird, [128] FRINGILLA, is placed near

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* Whilst crowding on material enlarges an object, pressure and condensation diminish the size of the aggregation. Compare MAGNUS, large, and MACER, lean.

† Πύξος, BUXUS, from its dense foliage, — "most dense" of Plini. "Buttmann makes it very probable that the radical notion of *πεύκη* is not, as usually supposed, that of bitterness, but of sharp-pointedness, the fir being so called either from its pointed shape, or from its spines." *Liddell and Scott.* Πεύκη, *fir*, is in Latin ABIES, probably for ABIEX, its adjective being ABIEGNUS, as SALIX, *willow*, gives SALIGNUS, *made of willow*.

[81] FRIGUTIO, to twitter; but the bird has a very robust bill, and is a seed eater, hence its number is that of FRANGO, to break. Here there is no real discrepancy; words like *break*, *crack*, being applied both to the sound and its accompanying phenomenon, the ear taking note of the former, and the eye of the latter.

[1] AH, alas, oh.
[12] EHO, ho! V-AH, oh!
[15] S-IC, thus; T-UNC, then.
[15] H-IC, here; H-OC, this.
[18] EX (*εκ*, *εξ*), out of.
[15] EGO, I.
[10] AI (*αἰ*), alas; AIO, I say.
[17] EJULO, I wail.
[27] ECCE, behold.[16]
[26] OCULUS, eye.
[27] B-ACCA, berry.
[27] N-IC-TO, I blink.
[27] N-IC-O, I beckon.
[27] SP-EC-IO, I see.
[27] S-AG-AX, seeing easily, ac-ute.
[6] ACHETA, a cricket.
[6] CICADA, a noisy insect.
[37] LOCUSTA, a grasshopper.
[2] ECHO, echo.
[33] V-OX, voice.
[33] V-AGIO, I sq-u-eak.
[33] F-AC-UNDUS, el-oq-uent.
[33] B-UC-INA, a trumpet.
[33] P-OC-ULUm, a cup.
[33] B-UCCA, a mouth, morsel.
[33] M-ICA, a crumb, bit.
[33] MAXILLA, a jaw.
[33] MUGIO, I bellow.
[33] F-AVC-ES, the gullet.
V-AG-INA, a scabbard.
V-ACO, to be empty.
[67] L-AC-UNA, a ditch.
[31] L-ACIO, I call.
[31] LEGO, I depute.
[31] LOQVOR, I speak.
[31] LUGEO, I mourn.
[31] P-IG-EO, I grieve.
[31] N-EGO, I say no.
[31] D-OCEO, I t-each.
[31] FR-IG-UTIO, I twitter.
[31] F-L-AG-ITIO, I demand.
[128] FRINGILLA, a finch.
[129] FRIGO, I roast.
[115] RINGOR, I open the mouth.
[115] STRIGO, I rest, take breath.
[91] S-T-R-IX, an owl.
STRIDEO↓ (*d* for *g*) *τρίζω*,↓ to stridulate.
[91] STRIGILIS, a scraper.
[119] R-IX-A, contention.
GR-AC-ULUS, a jackdaw.
ROGO, I ask, beg.
PROCO, I demand.
PRECOR, I pray.
[115] RICTUS, the mouth.
RUCTUS, eructation.
RAVCUS, harsh.
RUGA, a w-rinkle.
RIGOR (*ῥῖγος*), stiffness.
FRIGEO, I freeze.
FRICO, I rub.
[123] FRANGO, I break.
FRAXINUS, the ash.
PL-ANGO, I beat.
PLAGA (*πληγή*), a blow.
PLECTO, I punish.
PLECTO (*πλέκω*), I plait.
[62] FLECTO, I bend, turn.
[58] FLOCCUS, a lock of wool.
[62] LUCTOR, I wrestle.
[62] LIGO, I tie.
[58] LICIUM, a thread.
[44] LIGO, a hoe, a rake.
P-EC-TEN, a comb.
PLICO, I fold.
[44] LAXUS, sl-ack, wide.
PL-ACENTA (*πλακοῦς*), a cake.
FLACCUS (*βλὰξ*), flaccid.
FL-AGELLO, I whip.
[124] FR-UX, produce.
[125] N-UX, a nut.
[126] F-AG-US, the beech.
[5] AC-EO, to be tart.
[5] ACIES, an edg-e.
[80] ACUS, a needle.[78] [66]
MUCRO, a point.
MACERIA, a garden wall.
[8] EGEO, to ach-e.
[42] ICO, I strike.[47] [128]
[78] ICTUS, a blow.
[42] J-AC-EO, I throw.
[42] OCCO, I harrow.
[116] S-AVC-IO, I wound, kill.
S-UG-ILLO, I strike, re-vile.
SAVCIUS, sick.
SIGNO, I mark, express.
V-EX-O, I pl-ague, affl-ic-t.
VICTIMA, a victim.
TR-UX, fierce.
L-AC-ERO, I tear.
LACERTA, a liz-ard.
S-AXUm, a rock.
SECO, I cut, wound, go.
SICA, a d-agg-er.
SICILIS, a sickle.
N-EC-O, I slay.

NOCENS, per-n-ic-ious.
NOX (*νύξ*), night.
NIGER, black.
NUGAE, trifles.
PECCO, I sin.
P-EJ-OR, worse.
[42] AGO, I move, drive.
S-AG-ITTA, an arrow.
T-IG-RIS, a tiger.
[27] IGNIS, fire.
[26] FL-AG-RO, I burn, glow.
FOCUS, a hearth.
FAX, a torch.
[118] T-IG-N[m], a beam.
[87] L-IG-NU[m], wood.
B-AC-ULUS, a stick.
AXIS (*ἄξων*), an axletree.
GR-AC-ILIS, slender.
L-ONG-US, long.
M-AC-ER, m-eag-re.
V-AG-OR, I wander.
S-EQ-VOR, I follow.
[42] FR-EQ-VENS, frequent.
L-INQ-VO, I leave.
F-UG-IO (*φεύγω*), I fly.
N-IX-OR, I rest on, strive.
[124] F-AC-IO, I m-ak-e.
FACIES, appearance.
[96] PEGMA (*πῆγμα*), a m-a-ch-ine.
F-AEC-ULA, dregs.
M-AC-ULA, a stain.
P-IG-MENTU[m], paint.
F-ING-O, I make.
F-IG-O, I fix.
FICTUS, feigned.
F-IG-URA, shape.
L-OC-O, I place.
L-EC-TUS, a bed.
L-EG-O, I collect.
L-UC-RU[m], gain.
[141] AUG-EO, I augment.
[141] M-AC-TUS, augmented.
[141] M-AG-IS, more.
[157] M-AG-NUS, b-ig.
M-AG-ISTER, a master.
R-EG-O, I dir-ec-t.
P-ANG-O, I fix, agree.
PIGNUS, a pawn.
PACTUS, bargained.
PL-AC-ATIO, a pacifying.
P-AC-O, I pacify.
[151] P-AG-US, a village.
[151] V-IC-US, a village.
[152] P-UG-NUS, the fist, a handful.
[158] PUGNO, I fight.
PUNGO, I stick, sting.
πάγουρος, a p-ung-ar, (spiny lobster).
PUGIO, a dagger.
SP-IC-A, a spike.
T-ANG-O, I touch.
T-AC-EO, I am silent.
[97] L-ING-O, I lick.
[60] LINGVA, the tongue.
[92] D-UC-O, to draw, t-ug, g-et.
[92] D-IG-NUS, tak-e-worthy.
[92] D-EC-ENS, decent.
[92] DECUMANUS, great.
[92] DICO (*δικάζω*), I take, give, proclaim, say.
[92] DICO, I say, assign.
[92] DIGITUS, a f-ing-er.
[92] DEXTER, the right hand, m-ight.
[92] DECE[m] (*δέκα*), ten.
[92] INDEX, a sign.
[92] INDICO, I show, declare.
[42] DEGO, (DE, AGO,) I live.
TR-AH-O, I draw, take.
TR-AC-TO, I dr-ag, str-ike.
V-EC-TO, I convey.
[26] LUCEO, to light, glitter.
L-IQ-VEO, to be liquid, clear, plain.
AQ-VA, water.
M-AC-ERO, I s-oak in l-iq-uor.
M-UC-IDUS, slimy.
L-AC-RIMA, a tear.
LACUS (*λάκος*), a lake.
ST-AG-NUm, a pool.
R-IG-O, I irrigate.
S-ICC-US, dry, thirsty.
S-ICC-O, I dry, drain, suck.
SUGO, I suck.
SUCUS, juice, sap, v-ig-or.
SANGVIS, blood, force, race.
V-IG-EO, I live, am active.
F-EC-UNDUS, fertile.
V-IC-TITO, I feed on.
V-EG-ETUS, quick, fresh.
R-EC-ENS, growing, fresh.
RACEMUS, a cluster.
SEGES, seed, corn, profit.
SAGINA, food, fatness.
P-IX, pitch.
P-ING-VIS, fat.
P-EC-TUS, the breast.
P-IG-ER, slow, dull.
P-EC-U, sheep, cattle.
GR-EX, a flock.
[58] L-UC-US, a wood.
[62] NEXO, I bind, connect.
[72] STR-ING-O (*στράγγω*), I grasp, tie.[62]
[62] V-INCO, I conquer.
T-EX-O, I weave, build.
T-OG-A, a gown.
T-EG-O (*στέγω*), I cover, st-ick away.
S-OC-IO, I join, associate.
MAS (for max?), a male.
TUSSIS (for tuxis?) a cough.

§ 25. CHINESE.

Chinese being spoken with a peculiar intonation, the marks of accent and length used in printing it, indicate the tone, and where this is different, but the elements identical, the words are considered to be distinct. In fact it is less of an error to use T for L, than to use a wrong tone. The examples are from Medhurst's dictionary of the Hok-këèn dialect, and the orthography English, ch, y, ng, having their power in *chip*, *young*. The examples will be those corresponding to the Welsh, Greek, and Latin, already given, commencing with those which have a reduplicated guttural, as k–k, k–ng, y–k, or its transmutation (with English ch, as in speak, speech,) ch–k.

§ 26. kek, bright; keng, very bright; gâng, bright; gông, sunrise; hông, red; yàng, to illumine; yang, the sun; cheng, brightness; hong, luminous, clear; (sëang, cloth of a light yellow color, as if from sè, cloth, and eng, bright).* Jakutish, tshaghyrgā, to radiate, lighten; tshokyr, flint; tshoχ, a burning coal; dzhangkii, to be clear, transparent. The mind associates a ray, a spear, and a shoot; hence we find

§ 27. kek, a spear; hong, the point of a weapon; keng, a stalk of corn; chek, a blade of grass; yang, young shoots of rice, calamity; yāng, nourishment; yáng, nausea; (seng, to be born, alive).

§ 28. go'k, a peak, the point of a sword, a crocodile; ga'k, a hill; gek, rugged like hills, lofty; gōng, high.

§ 29. yëu'k; a sound, a voice, bright, clear; yúng, to leap, a bubbling fountain, bold; yea'k, to leap; heng, to walk, to travel; (ông, to walk quickly; sëang, hasty); cheng, hasty walking, afraid; hek (and lek), to be afraid; che'k (and tëuk), to advance; (e'k, to lead hastily); hēng, to accompany; hông, haste; hëùng, to hasten. (In German *keck* means pert, bold, nimble; Eng. quick). Jakutish, yk, to hasten.

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* In like manner, it is probable that the Sanscrit root rāp'h, *to stir, to break.* Latin, RAP-IO, (Eichhoff, No. 525,) is composed of aR, *to go, to reach,* (E. No. 495,) and ab, *to go,* (E. No. 22,) or āp, *to occupy, to hold,* (E. No. 23.)

§ 30. The following examples, in continuation of the preceding, are to be read across the page. The first column contains the root, to which the prefixes s-(r-)t-, l-, are added in the second, third, and fourth columns. A few parallel forms in Greek, Latin, Welsh, Gaelic, and Hebrew are added, examples in r- being placed with its cognate s-.

§ 31. The force of the Chinese prefixes k-, s-, t-, (l-, see § 20,) is observable in k e, a pearl; to ridicule; to pray; to sell;* k ē, to fear; k è, a stalk; proud; hasty; k ê, happy; k a e, violence; harmony. s ē, to look at; to spread out; a connecting thread; ardent; to swear; day-break; a peak; s e, an arrow; to wet; silk; spittle; the beginning; s è, power. t e, to blame, to kill; t é, to revile; to oppose; t è, to extend to; to display; t ê, a pond; to walk; t â, to frisk; to be burnt.

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* When definitions are separated by semicolon, they are represented by different Chinese characters of the same name; when by a comma, they define a single character.

As the Latin final *m* indicated a nasal vowel, it is printed as in STAGNUᵐ, that it may not have the prominence of a real (and a labial) consonant letter.

The examples of Jakutish (yakutish) are from Böhtlingk, and in the absence of the proper types, his Russian orthography has been roughly turned into English. It could not have been done critically without considerable explanation, and the same remark applies to the few Hebrew words introduced.

Should the suggestion that ABIES is from ABIEX be correct, the following table may be constructed: —

A B I E G N U S ,	*of fir.*
A B I E .. .. .. S ,	*the fir.*
P I .. C .. .. S ,	*pitch.*
F .. A C .. .. S ,	*a torch.*
F .. O C .. U S ,	*a hearth.*
π ε ύ κ .. η .. ,	*the pine.*
S-P I .. SS .. U S ,	*dense, etc.*

Here SPISSUS is probably for *s-pic-sus*, from the root of *pac*, no. 142.

In the following examples, a few of the words are not placed in the column with those having the same initial — for the purpose of accommodating modifications of idea. Thus, Hungarian *szak*, § 36, stands in the first, instead of the second column.

√	S—	T—	L—
§ 32. eng, *clear, bright.* ek, *the brightness of fire.* (Latin, IGNIS, *fire.* Gaelic, ogh, *pure;* eag, *moon;* ece, *clear;* uige, *a jewel.* Hung. ég, *the stars.* Jakutish, öng, *color;* ing, *red on the cheeks.*)	seng, *bright, to burn; sunrise.* song, *clear, pleasant, grand.* (Welsh, rhaca, *a show.* Gaelic, eugas, *likeness.* Jakut. saχ, *to strike fire.*)	teng, *a lamp.* t'hëung, *dry and hot.* t'hun, *a spark.* tông, *red.* sec, *dry.* (Lat. SICCUS. W. têg, *clear, fair.*)	lēng, *good, fine.* lóng, *the appearance of fire.* lóng, *bright, clear.* lĕu'k, *green.* (Lat. LUX, § 19. Heb. LâHâb, *a flame, a sword-blade;* LaHat', *to burn,* § 23.[27])
êng, *a fire-fly.*	seng, *a star.*	t'hong, *the sun darkened.*	lêng, *the rising sun,* § 17.
§ 33. eng, *a flower.* êng, *flowery.* ōng, *to prosper, bright.*	seng (and sey), *luxuriant herbage.* (Heb. rāχăn, *to sprout leaves;* shāghāh, *to grow.*)	t'hok, *bamboo shoots; to burst out.* te'k, *a sort of reed.* (W. tug, *prosperity.*)	lông, *overgrown grass.* lĕu'k, *high grass.* (Welsh, llig, *what shoots.*)
§ 34. éng, *beards of grain, an awl;* a'k, *a spindle.* ong, *a wasp.* (L. ACUS, *a needle,* § 23[5]; ACULA, *an awl.* Gael. acht, Hung. szeg, *a nail.* Turkish, aug; Jakut. oχ, *an arrow;* igi, *a file.*)	sek, *to stab, a sting.* sok, *a lance, a spear;* san,* *skewers.* (Heb. rāχăχ, *to break;* rāqăq, *to spit.* Lat. SAG-ITTA. Gr. ῥάχος.[108] W. such, *a snout.* rhuch, *a husk.*)	tek, *an arrow point.* teng, *a nail.* t'hek, *to slaughter.* (Lat. TANGO, *I touch, at-tack.*[92] Heb. tāqăχ, *to strike.* Jakut. tong-syi, tshok-yi, *to beat, knock;* dzhang, *pestilence.*)	lêng, *any thing pointed and angular.* lông, *to pierce.* lōng, *corner of a hill.* long, *thin, meagre.* (Lat. LINGVA, *the tongue.*[50] Sanscrit, nakk, *to pierce;* naç,† *to destroy.*)
§ 35. êng, *a grave;* (ὄγμος, *a furrow.*[58]) ong, *hump-backed.* (Gaelic, aighe, *a hill;* acha, *a mound.*)	sèk, *the hollow of a grave.* sëung, *high; the point of a hill.* sëûng, *a fir-tree.* sëáng, *to ascend, exalt.* (Heb. rāghăm, *to heap up.*)	teng, *a mound.* teng, *to ascend, ripen.* téng, *the top.* (Welsh, rhic, *a groove;* rhych, *a furrow.*†)	lêng, *a large mound.* lóng, *a tomb.* (W. lloc, *a mound, a dam.*)
§ 36. e'k, *the noise of splitting.* (Latin, IC-TUS, *a blow.* Greek, ἄγω, *I break.*[42] Hungarian, ék, *a wedge;* szak, *a fragment.* Jakut. ang-y, *a part;* ang-ai, *open;* ong-oi, *an aperture.*)	sek, *to cut off, to split wood.* (Heb. sāhhăph, *to scrape.* Lat. SEC-O, *I cut off.* ῥωγὰς, *split.*[116] W. sig, *a shatter, a bruise;* rhecio, *to hackney.* Heb. rēhheh, *a mill-stone.*)	tëuk, *to hack, a hoe.* tok, *to scrape, to hack.* te'k, *any thing made shorter.* (W. toc, *what is abrupt;* tocio, *to d-ock;* twc, *a cut.* Jakutish, löng, *split wood.*)	lok, *a sabre wound.* lek, *to cut, scrape; strength.* lēng, *to cut off.* lâng, *to beat, strike.* (Lat. LIGO, *a hoe.*[44 80] Heb. rāχăsh, *to strike with the foot.*)
§ 37. ĕng, *to s-ing.* eng, yung,* *the singing of birds.* èng, *the sound of hallooing.* àng, *disorderly.*	seng, *a flute.* (Gr. ῥόχ-θος, *a loud noise.*[91] Lat. RIXA, *contention.* Jakutish, sang-a, *voice, outcry.*)	teng, tin, tang,* *a t-inkling.* tông, *an echo.* tong, *the sound of a drum.* t'hong, *the noise of water.* tóng, *the noise of falling in water.*	lông, *the tinkling of gems.* lōng, *to strike against; the humming of birds.* lêng, *a small bell.* lëûng, *the sound of a drum.* (Jakut. lyngkyr, *a clanging.*)

§ 38. ak, *a ca-ck-ling.* ek, *the noise of l-augh-ing.* (Gael. ac, *speech;* oc, *a poet.* Jakutish, ŏghüi, *to choke.*)	sek, *a chirping.* (Hung. tik, tyúk, *a hen.*)	tak, chëuk, *the noise of calling fowls.* t'hek, *to vociferate.* t'hëuk, *to rail at.* tëuk, *to thump.* tok, *to beat.*	lek, *a kind of flute.* lek, *the noise of water.*
§ 39. èng, *to reply.* yín,* *to promise.* yîn, *to say, to declare.* yín, *the sound of thunder;* (ἠχώ, *echo,*[1 6 11–14]. Jakutish, aχ, *to count, to tell.*)	seng, *a voice, a noise.* (Heb. rāhăm, *to make a noise;* rĕχă, *thunder;* rēχă, *outcry.* Lat. ROGO, *I ask.* Ger. sag-en, *to say.* W. rheg, *an utterance.*)	têng, *to warn.* t'héng, *to boast.* teng, *a clap.* tëûng, *reiterated;* ek, *a stoppage in the throat.* (Lat. DIC-O, *I say;* TUSSIS, *a cough,* for TUXIS? W. tâg, *a strangle.*)	lêng, *talkative.* leng, *to command.* lêng, *to insist upon.* (Gr. λέγω, *I speak*[20–25]; λόγος, *a word.* Lat. LOQ-VOR, *I sp-eak.* LOCUSTA, *a stridulating insect.*)
§ 40. êng, *water flowing back.* ang, *overflowing.* ak, *to irr-igate;* ak, *to drip;* yúng,* *a fountain;* yûng, *water flowing quietly.* (Latin, AQ-VA, *water.* Jakut. ygyt, *an overflow.*)	seng, *a rising of water.* (Heb. rāhăt, *to flow.* W. soegi, *to steep;* swg, *a s-ouk.* Lat. RIG-O, *I irrigate.* Jakutish, sĭk, *moisture, dew.*)	tông, *a pond.* têng, *a dam.* tek, *the appearance of water.* tëàng, *to inundate, the tide.* teēng, *brimful.* (Latin, S-TAG-NUM, *a pond;* STAGNO, *to inundate.* Jakutish, toχ, *to pour out.*	long, *a wave.* lêng, *superfluous.* lek, *overplus.* (Lat. LACUS, LIQVIDUS. Heb. logh, *a deep cavity.*)
§ 41. ek, *a cord, a series.*	sàn,* *a thread.* sëèn, *a thread, connecting line.* sek, *fine cloth.* (W. syg, *a chain.* Lat. SOC-IO, *I join.* Heb. rāχăs, *to bind on, or to*).	tek, *to tie.* teng, *a cord.* t'hóng, *a thread, a line.*	lok, *joined, a thread.* (Lat. LIG-O, NEC-TO, *I tie;* LIC-IUM, *a thread.*)
§ 42. óng, *to go;* eng, *to encounter.* (Lat. AGO, *I move, drive.* Gael. eigean, *force*).	sëang, *to wound.*	te'k, *to oppose.* tong, *to run against.* tëu'k, *to advance.* (Jakutish, yk, *to hasten.*)	lĕu'k, *to kill.*

* The vowel *a* generally requires *n* after it, by a law which, out of the English "hang," would be likely to make *han* or *heng*. Similarly "ing" might become *yin*, and "ung" *yung*. Among the root words of the first column are ang, eng, ong, but not *ung, ing; ag, og, eg, ok.*

† This an example of the *polarity* of words, like the English *dyke*, a mound, and an excavation.

2. Supposed Runic Inscriptions. By Dr. A. C. Hamlin, of Bangor, Maine.

I have the pleasure of presenting to your notice some casts in plaster of a supposed Runic inscription, which appears upon a ledge of hornblende on the island of Monhegan, off the coast of Maine.

It was my first intention merely to present these casts, without making at present any remarks, but as I have been requested to express my opinions, I will endeavor to give some explanation.

I will not venture to say that these characters are Runic, but will only suggest the probability of their being made by some illiterate Scandinavian, whose knowledge of the Runic form was very imperfect. If they are recognized as Runic, they belong to that compound, complex, and pointed class which renders an interpretation extremely difficult. The pointed class, however, belongs to those times in which the Northmen are supposed to have visited our shores, — the tenth, eleventh, and twelfth centuries. The earlier the rune the more simple it was in form and the more easy of translation, but the modifications and corruptions of later periods have confused and changed the character in a great degree. There were complete monographs formed by many runes clustered upon a single stem, and with such confused and irregular lines that interpretation was almost impossible. As illustrations of the subject I have drawn, upon the blackboard, some examples from the Binderuner and from the pointed class — a line of marks from Sodor; another from a brooch found at Largs; another from the Ferroe Islands, and still another from the Kobelicher Uune.

To give an example of the difficulty with which these Runic scrawls were translated, I will relate the instance connected with the assassination of Snorre Thurleson. A note written in Runes, and warning Snorre of the danger of assassination was sent to him, but neither he who was so justly titled the Northern Herodotus, and who was so deeply versed in the lore, nor any of his attending friends were able to interpret its meaning.

There is among the Icelandic accounts of the early voyages to this country, a narration which serves to support the Scandinarian theory of this inscription.

Lief the Fortunate sailed in the year 1000 with thirty-five companies in search of those lands which Bjarne had asserted that he had seen in the distance. After passing Newfoundland, which they called Helluland and Nova Scotia, to which they gave the name Markland, they arrived at an island, after sailing two days and nights. This island may be supposed to have been Monhegan, from the following circumstances. The Northmen saw on the horizon mountains blue with distance. Such the Camden Mountains appear to the observer at Monhegan. The island lay direct east from the main land. This is the position of Monhegan. From this island they sailed into a river close by, and were wafted by the tide into a lake whose waters teemed with the largest and finest salmon. Near by they built their booths, which they called Liefsbudir, and passed the winter.

This river is well represented by the Kennebec, which flows into the ocean close by Monhegan, and Merry-Meeting Bay, the so-called confluence of the Kennebec and Androscoggin Rivers corresponds admirably to the lake before mentioned. Moreover, I am informed by Mr. Williamson, the historian of the State, that about two centuries ago, the early settlers, when clearing the lands on the banks of the Kennebec above its confluence, discovered what appeared to be the remains of chimneys and mouldering ruins, over which grew an ancient forest. These may have been the remains of Liefsbudir, — the relics of seven centuries.

If this scrawl was not made by Lief or his companions, it may have been made by Karlsfne, during the voyage made in search of the lost Torhall, when sailing north from Vineland he came to lands which presented in every view noble and majestic forests; or, perhaps, by Thorwald in his expedition in the direction of Maine in the year 1004.

For three centuries the Icelandic accounts maintain that the Northmen visited our coasts, and it is not improbable that some of the bold Vickings were attracted to this island whose advanced position and lofty heights presented the earliest view of land to the mariner approaching the coast of Maine, and here they may have rudely attempted to commemorate their discovery, or inscribe hurriedly to the memory of a departed comrade.

I have little doubt but that the rock on which this inscription occurs was fissured at first somewhat by nature, and that the advantage was perhaps embraced by the Scandinavian, but I would like to inquire of

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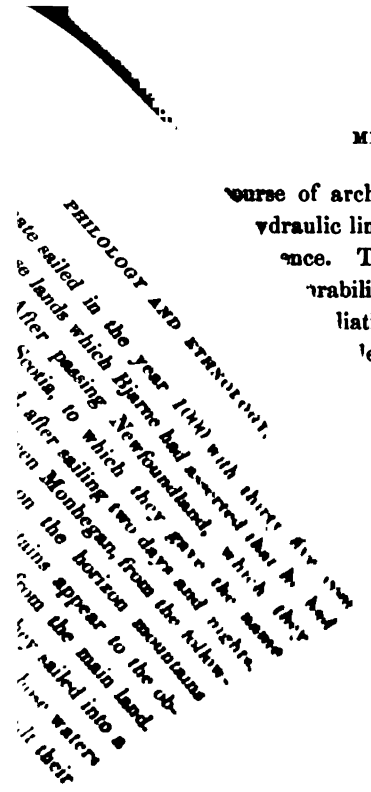
I will not venture to say that only suggest the probability Scandinavian, whose knowl fect. If they are recogni complex, and pointed cla difficult. The pointed the Northmen are s eleventh, and twelft ple it was in form tions and corrupt character in a by many run and irregul illustration examples of mark from T we e r

[illegible] Camden Mountains appear to the [illegible] direct east from this island they sailed into a [illegible] Near by they built their [illegible] which form into [illegible] they [illegible]

[illegible] Runmake sailed in the yea [illegible] those lands which Bjarne had [illegible] After passing Newfoundland [illegible] Nova Scotia, to which they gave [illegible] an island, after sailing two days and [illegible] to have been Monhegan, from the [illegible]

[illegible] uty of efflorescent salt, [illegible] asonry at Fort Adams, New- [illegible] y informed you, is highly destructive [illegible] ppears, and whoever can discover a com- [illegible] st its formation, such as to admit of an easy [illegible] ice, will lay engineers and builders under perpet- I have thought it might be one step towards so desir- [illegible] if you would call the attention of such chemists as may be [illegible] ance at the Albany meeting to this important problem.

[illegible] facts are briefly these: brick masonry laid in hydraulic mortar, [illegible] exposed to the action of sea air, soon exhibits an efflorescence over the entire exterior surface. The efflorescent crystallization first forms under the outer, hard coating of the brick, and then an exfoliation of brick scales results. The harder crust being gone, each successive crystallization throws off a portion of brick dust, until in a few years an inch or two, or even whole bricks, will be disintegrated. The softer bricks are more rapidly destroyed, but none wholly escape. At Fort War-



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tracing out of these reactions, and in the use of some
ient to prevent or modify the combining processes leading
destructive crystallization. Any method, not chemical, would
seem of doubtful efficacy, and no chemical process has yet been employed. By an appeal to the multitude of chemists, it is possible that some one may hit on the fortunate *stabilitator* of existing combinations, or *divertor* from efflorescent combinations. It would be difficult to estimate the annual value of a process answering this requirement with practical facility; but it would be of immense benefit, even on our fortifications and light-houses alone.

Our hydraulic limes contain soda and potassa, which seem to penetrate the brick, under the influence of the sea air, and thence to protrude under new combinations in crystals of the character now transmitted. I have seen two or three embrasure soles, which had been for several years essentially unventilated, on which a crop of filamentous crystals as delicate as cotton wool, formed a coating of about one inch

geologists whether crystallization, could, by its fissures, form this long series of characters; and precluding the theory of diluvial or glacial agency, whether any one would dare to ascribe them to that force hidden and mysterious which Camerarius and Tournefort were wont to call the play of nature.

PRACTICAL SCIENCE.

I. MECHANICS.

1 On Efflorescence from Brick Masonry. By Lieut. E. B. Hunt, U. S. Corps of Engineers. (In the form of a letter addressed to Professor E. N. Horsford.)

My dear Sir. — I herewith inclose a quantity of efflorescent salt, scraped from the surfaces of brick masonry at Fort Adams, Newport. This salt, as I have already informed you, is highly destructive to the bricks on which it appears, and whoever can discover a complete preventive against its formation, such as to admit of an easy application in practice, will lay engineers and builders under perpetual obligation. I have thought it might be one step towards so desirable a result if you would call the attention of such chemists as may be in attendance at the Albany meeting to this important problem.

The facts are briefly these: brick masonry laid in hydraulic mortar, and exposed to the action of sea air, soon exhibits an efflorescence over the entire exterior surface. The efflorescent crystallization first forms under the outer, hard coating of the brick, and then an exfoliation of brick scales results. The harder crust being gone, each successive crystallization throws off a portion of brick dust, until in a few years an inch or two, or even whole bricks, will be disintegrated. The softer bricks are more rapidly destroyed, but none wholly escape. At Fort War-

ren the intrados course of arch bricks is laid in fat lime mortar, because the effect of hydraulic lime has been found to be very great in inducing this efflorescence. The same type of action as in Brard's process for testing the durability of building materials, is obviously at work in the successive exfoliations of brick masonry. The origin of the efflorescent salt is, doubtless, in great part from the hydraulic cement and brick, but there is not that precise knowledge of facts which ought to be attained in so important a matter. The whole problem needs thorough investigation at the hands of chemists, for it is altogether a chemical one and not one for the engineer. The only theory of causation of which I am aware, is that of General Totten, the chief engineer, who reasons thus in the premises. *Drying* is an essential condition for all efflorescent crystallization. By saturating or coating with substances strongly absorbent of moisture, the dryness necessary for efflorescence may be prevented. Solutions of soft soap, chloride of calcium, bitter water, etc., on trial seem to obviate efflorescence in small pieces of brick, but give unsatisfactory results in large masonry masses. This theory, ingenious though it is, seems too much like an application of main strength, and certainly is rather treating a symptom than the disease. This efflorescence is the result of certain chemical reactions in the masonry masses; and the normal remedy would seem to lie in a clear tracing out of these reactions, and in the use of some new ingredient to prevent or modify the combining processes leading to the destructive crystallization. Any method, not chemical, would seem of doubtful efficacy, and no chemical process has yet been employed. By an appeal to the multitude of chemists, it is possible that some one may hit on the fortunate *stabilitator* of existing combinations, or *divertor* from efflorescent combinations. It would be difficult to estimate the annual value of a process answering this requirement with practical facility; but it would be of immense benefit, even on our fortifications and light-houses alone.

Our hydraulic limes contain soda and potassa, which seem to penetrate the brick, under the influence of the sea air, and thence to protrude under new combinations in crystals of the character now transmitted. I have seen two or three embrasure soles, which had been for several years essentially unventilated, on which a crop of filamentous crystals as delicate as cotton wool, formed a coating of about one inch

deep. In most instances, wet weather runs these fine crystals into a mass or crust, from which new ones again form in dry weather. Whether the fact that the efflorescence in question is limited to the seaboard, finds an adequate explanation in the fogs and moisture of the sea exposures, I cannot say; but this cause would seem to be inadequate, and if so, the saline ingredients of sea-water must take part in the process. The transfer of sea salts in spray borne by the wind, is not to be overlooked. In this connection it may be well to call attention to the bearing of the experiments by Vicat and others, on the destructive action of sea-water on certain mortars, recorded in the *Comptes Rendus* and elsewhere.

It is a general fact, that the chemistry of mortars and cements needs additional investigation; but this special problem of efflorescence from brick masonry is one more urgent than the others, as the lack of a proper solution is, to a considerable extent, prohibiting seaboard brick masonry, and compelling a resort to more expensive stone constructions.

II. MISCELLANEOUS.

1. On Systematizing the Abbreviations of Titles of Periodicals, Transactions, etc. By Lieut. E. B. Hunt, U. S. Corps of Engineers. (In the form of a letter to Professor A. D. Bache.)

In preparing, under your direction, an Index of the titles of papers on subjects involved in the operations of the Coast Survey, gathered from all the Scientific Periodicals, Transactions, Memoirs, etc., to which I can obtain access, one unanticipated difficulty has again and again perplexed me. Every title which I take out must contain an abbreviation of the title of the work from which it is taken; hence I have been obliged to write many thousands of these abbreviations while gathering the materials for this Coast Survey Index. It is therefore

a matter of considerable moment that these abbreviations should be as brief as possible while serving their primary purpose. The special difficulty to which I refer is, that there is no authentic code of abbreviations in general use, and that many of those particular forms which I have encountered are long, unwieldly, indeterminate, and conflicting. In many instances I have to coin abbreviations, and in many others there are insuperable objections to such as are now more or less in vogue.

This subject is more important than it might at first appear, for these abbreviations are not only written and printed thousands of times each year, but every cultivator of science must, as a part of his special training, become familiar with the abbreviations which concern his own departments of research, as a kind of special alphabet. Hence the abbreviated forms ought to be as short as possible without losing distinctness, to save needless writing and memorizing. This will be better appreciated when we bear in mind that the list of Agassiz and Strickland contains one thousand two hundred and eighty-four titles of acts, journals, and collections of papers on zoölogy and geology alone, without being complete even on those subjects, while each of these titles must probably have one or more abbreviations in use. We ought not to forget that we are even now but at the beginning of scientific expansion, and that each succeeding year is bringing into being accessions to the long array of scientific records. It is therefore of the greatest prospective importance that principles for abbreviating titles should now be settled, and that practice should as rapidly as possible be brought to a uniformity based on these principles. In 1856 we should bear in mind that the year 2000 is to come, and that then the records of science will be found under at least a myriad of separate periodical titles, and each series will contain matters for future reference, just as we now refer to the various early series of Transactions for the investigations of our predecessors. The results, on being aggregated, would doubtless make a proper subject for publication by the Smithsonian Institution. It seems to me that some plan of this general character would be feasible. Should the American Association share this impression, it is in its power to initiate the measure, and test its practicability with no fear of bad results. The demand of coming generations will be for freedom of memory, and our duty is to make their mnemonic burdens a minimum.

I will cite here a few instances, and these not the worst, to show how unsettled and chaotic our existing practice of abbreviation is. The American Journal of Science is abbreviated to

Am. J. Sci., by Prof. Dana, one of the editors.
Am. J., *Amer. J.*, *Amer. Jour.*, } by Agassiz and Strickland, in Index
Jour. of Sci., by Poole, in his Index.
Sill. Am. J., by Liebig and Kopp, in Annual Report, etc.
Sillim. J., by Dr. Schubarth in his new Repertorium.

The Philosophical Transactions of the Roy. Soc. London, are abbreviated: —

Phil. Tr., *Phil. Trans.*, } by Agassiz and Strickland.
Philos. Transact., by Reuss, in his Repertorium.
Ph. tr., by Dr. Young, in his Index.

The Comptes Rendus as follows: —

Compt. Rend., by Liebig and Kopp.
Compt. r., by Schubarth.
C. r., *C. R.*, *Comptes Rendus*, *Compt. Rend.*, } by Agassiz and Strickland.

The French Academy and Institute Memoirs are thus abbreviated: —

Mem. de Paris., by Reuss.
A. P., *S. E.*, } by Young.

Mém. Acad. Sc. Par., *Mém. Acad. des Sc.*, *Mém. Sav. étr.*, *Mém. s. Prés. à l'Acad.*, } by Agassiz and Strickland.
Mem. Inst., is common for the later Memoirs.

This chaotic diversity is common to nearly all abbreviations in the above-cited works, where they must have received rather special

deliberation, and by referring to individual modifications by separate investigators, a perfect Babel of usage will be found. That this is a real evil, I assume none will question. Can it be corrected, is a question on which different opinions will probably be found to exist. Certainly correction cannot come without some effort, and without the aid of time. There is time enough; there ought to be effort enough. Things cannot be worse, for there is now nothing fixed. Conservatism has nothing to fear in this instance.

It has occurred to me as a plan which would stand a respectable chance of success for the American Association to initiate a reform by consigning the subject to a special committee with instructions to invite, in behalf of the Association, the coöperation of other countries concerning their own periodicals, etc. Thus, for instance, the Am. Assoc. might fix such abbreviations for all American scientific issues. It might by correspondence invite the coöperation of the British Association or Phil. Soc. for British periodicals, etc.

Some principles of abbreviation might here be elaborated, but I shall only say in brief: First, that abbreviations should be as brief as possible without becoming obscure. The motto should be, "Abbreviations that are abbreviations." Secondly, only the leading, characteristic words of a title should find place in an abbreviation. Connecting particles should be thrown out. The possessive or genitive form, which is by far the most frequent, can be easily disposed of by using the apostrophe or possessive sign for *of* or *of the*. Thus, Am. J.' Sci.; J.' Soc.' Arts. Thirdly, certain words of very frequent occurrence should be reduced to their initial as an abbreviation; as J. for Journal; M. for Memoirs; N. for New, Nouvelle, Nuovo, Neue, Nova; others to two initials, as Ph. for Philosophical; Tr. for Transactions; An. for Annals; Ac. for Academy, etc. In general the abbreviation for the same word, when frequently occurring, should be constant and a practical minimum in all combinations, and when possible, the same in different languages. Fourth, location should, as a general rule, enter each abbreviation in some form; as, M.' Ac.' Par. for the Paris Academy Memoirs; Am. Ph. Tr., American Philosophical Transactions. These hints will suffice to show that there are principles in this matter which should be carefully elaborated and weighed.

It may be that the coinage of abbreviations under compulsion which has fallen to my lot, leads me to attach an undue importance to the

subject, but I am confident that a like experience would make most persons quite as desirous of seeing an *established code of abbreviations for all the world* as I have become.

Very truly, yours, &c.

E. B. HUNT, Lieut. Corps of Eng's.

The following papers were presented and most of them were read. They are not printed, because no copy was furnished for publication: —

I. MATHEMATICS AND PHYSICS.

1. The Elements of Potential Arithmetic. By Benjamin Peirce.
2. Analytical Discussion of the Motion of a Body under the Action of Central Forces. By Benjamin Peirce.
3. Morphological Discussion of the Laws of Central Forces. By Benjamin Peirce.
4. Motion of a Body upon a Solid of Revolution, when the Force is directed towards a point upon the Axis. By Benjamin Peirce.
5. On the Increase of Accuracy in the Mean Result, by Augmenting the number of Observations. By Dr. C. H. F. Peters.
6. On the Interpretation of some Cases of Apparent Geometric Discontinuity. By J. B. Cherriman.
7. Note on the Rotation of a Rigid Body. By J. B. Cherriman.
8. The Fundamental Numeric Series, and Divergence of Radiating Parts, reduced to a Simple Organological Idea. By Dr. T. C. Hilgard.

9. Report on the Present State of Organic Chemistry. By Dr. Wolcott Gibbs.

10. On the Advantage of Observing a Lunar Spot instead of a Limb, in transits, for determining the Difference of Longitude. By Dr. C. H. F. Peters.

11. Researches concerning the Comets of 1783 and 1793. By Dr. C. H. F. Peters.

12. On the Next Appearance of the Periodical Comet of Thirteen Years. By Dr. C. H. F. Peters.

13. On the Physical Peculiarities of Comets. By Stephen Alexander.

14. A Report on the New Methods of Observation now in use at the Cincinnati Observatory: —

1. New method of right ascension, as to its limit of accuracy.
2. New method of declination, as to its limit of accuracy.
3. New method of determining personal equation and personal error.
4. New method of determining instrumental errors.
5. New method of determining clock errors.
6. Observations on changes of figure of materials.

By O. M. Mitchel.

15. On the Results of the United States Astronomical Expedition to Chili, for the Determination of the Solar Parallax. By B. A. Gould, Jr.

16. On some Special Arrangements of the Solar System, which seem to Confirm the Nebular Hypothesis. By Stephen Alexander.

17. Tidal Currents in Saturn's Ring. By Benjamin Peirce.

18. On the Relative Age of the different portions of the Moon's Surface, and the Catastrophe to which a large portion seems to have been Subjected. By Stephen Alexander.

19. Further Investigation relative to the Form, the

MAGNITUDE, THE MASS, AND THE ORBIT OF THE ASTEROID PLANETS. By STEPHEN ALEXANDER.

20. ON TABLES OF THE ASTEROIDS. By F. BRÜNNOW.

21. ON TEMPORARY STARS, AND THE SPHEROIDAL ORIGIN OF THE FORMS OF CLUSTERS AND NEBULÆ. By STEPHEN ALEXANDER.

22. ON THE PHENOMENA OF THE DISCHARGE OF ORDINARY ELECTRICITY. By JOSEPH HENRY.

23. REMARKS ON THE USE OF THE ANEROID BAROMETER.

24. ON A MODIFICATION OF NOREMBURG'S APPARATUS. By SANDERSON SMITH.

25. REPORT ON THE OBSERVATORY AT TORONTO. By J. B. CHERRIMAN.

26. ON THE PRODUCTION OF ROTARY CURRENTS IN AIR AND OTHER GASES; WITH A SPECIAL ILLUSTRATION OF A ROTARY CURRENT RENDERED LUMINOUS BY FLAME AND INCANDESCENT CHARCOAL. By Dr. D. B. REID.

27. ON THE FORMATION OF AIR BUBBLES BY DROPS FALLING ON THE SURFACE OF WATER, ETC. By WILLIAM B. ROGERS.

28. ON CERTAIN MOVEMENTS OF PONDERABLE BODIES, AND CERTAIN SOUNDS WHICH CANNOT BE TRACED TO ANY KNOWN PHYSICAL CAUSE. By Dr. HARE.

29. ON THE HISTORY AND THEORY OF THE INSTRUMENTS KNOWN AS ROTASCOPES, GYROSCOPES, ETC. By WILLIAM B. ROGERS.

30. ON THE FORMS OF THE ATOMS OF THE SIMPLE SUBSTANCES OF CHEMISTRY, AS INDICATED BY THEIR ATOMIC WEIGHTS, By STEPHEN ALEXANDER.

31. RESEARCHES ON THE AMMONIA-COBALT BASES. By Dr. WOLCOTT GIBBS, AND Dr. F. A. GENTH.

32. REMARKS ON OZONE OBSERVATIONS. By WILLIAM B. ROGERS.

33. On the Modifications of Sesquioxide of Chromium. By E. N. Horsford.

34. On the Waters of the St. Lawrence and Ottawa Rivers. By T. Sterry Hunt.

35. Notice of a Locality of Gigantic Crystals of Allanite, with Specimens. By William P. Blake.

36. On a Possible Modification of one of the Methods of Ascertaining the Density of the Earth. By Stephen Alexander.

37. Discussion of the Terrestrial Magnetic Elements for the United States, from Observations in the Coast Survey and others. By A. D. Bache, and J. E. Hilgard.

38. Notice of Observations to Determine the Cause of the Increase of Sandy Hook, made by the Coast Survey, for the Commissioners on Harbor Encroachments of New-York. By A. D. Bache.

39. Notice of Observations to Determine the Progress of the Tidal Wave of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments. By A. D. Bache.

40. On the Annual Duration of Sunlight on the Earth in Different Latitudes. By L. W. Meech.

41. On the Altitude and Physical Structure of the Appalachian System in the Region of the Black Mountains in North Carolina, compared with those of the White Mountains in New Hampshire. By A. Guyot.

42. Observations on the Andes in Bolivia. By J. R. Loomis.

43. The Plan of Reduction of the Meteorological Observations reported to the Smithsonian Institution, adopted by the Secretary. By James H. Coffin.

44. On an Improvement in the Anemometer. By Charles Smallwood.

45. Description of an Unique Form of Hail or Sleet. By Edward Hitchcock.

46. A Brief Exposition of the Absurdity of the Doctrine which represents that any Storm can be a travelling Whirlwind, unless as a Consequence of Centripetal Currents; or that if due to such Currents, it can have a diameter much more than eighty-one times the height of the Stratum of the Atmosphere within which it may be Generated. By Dr. Hare.

47. On the Meteorological Phenomena during the Epidemic of 1855, at Portsmouth, Virginia. By Nathan B. Webster.

II. NATURAL HISTORY.

48. On some Points in the Geology of the Upper Mississippi Valley. By James Hall.

49. On the Carboniferous Limestones of the Mississippi Valley. By James Hall.

50. Generalities of the Geology of Oregon and Northern California. By J. S. Newberry.

51. The Metamorphic Action of Silicious Thermal Springs. By J. S. Newberry.

52. Sketch of the Progress of Geology in Alabama. By M. Tuomey.

53. The Permian and Triassic Systems of North Carolina. By Ebenezer Emmons.

54. Some Observations on the Coal-Fields of Illinois. By R. P. Stevens.

55. Notice of a Remarkable Instance of Inclined Stratification in Warren county, New York. By J. D. Whitney.

56. Lateral Disturbance in the Surface Strata in the Sandstone Quarries of Newark, New Jersey. By Edward Hitchcock.

57. On some Euphotides, and other Felspathic Rocks. By T. Sterry Hunt.

58. On the Serpentines of the Green Mountains, and some of their Associates. By T. Sterry Hunt.

59. Observations on the Geology of the Region between the Mississippi and the Pacific Ocean, with a Map. By William P. Blake.

60. On the Results of Collections of Fossils during a period of Ten Years in the Limestones of the Lower Helderberg. By James Hall.

61. Proofs of the Protozoic Age of some of the altered Rocks of Eastern Massachusetts, from Fossils recently discovered. By William B. Rogers.

62. The Deposits of Fossil Fishes and Reptiles of Linton, Ohio. By J. S. Newberry.

63. The Tertiary Flora of the Upper Missouri. By J. S. Newberry.

64. On the Geological Position of the Remains of the Extinct Peccary of the North-west. By J. W. Foster.

65. Together with some Observations on their Dentology. By Jeffries Wyman.

66. Description of a Fossil Shell found in the Sandstone of the Connecticut Valley, probably belonging to the Genus Spherulites. By E. Hitchcock, Jr.

67. Exhibition of Fossil Cetacea from Maine. By A. C. Hamlin.

68. Mud-nests of the Tadpole, Recent and Fossil. By Edward Hitchcock.

69. On Animal Development: Part I. The Egg; Part II. The Embryo; Part III. One-celled Animals. By Louis Agassiz.

70. On Viviparity and Oviparity. By Louis Agassiz.

71. On the Classification of Turtles. By Louis Agassiz.

72. On the Organization of the Acanthocephala. By D. F. Weinland.

73. On the Influence of Light and Water on the Direction of the Plumule and Radicle in the Germination of the Seed. By James Dascomb.

74. Queries relative to some Indications of Human Instinct, as Illustrated by Primitive Arts. By Daniel Wilson.

75. The Value of Physical Conformation as an Element of Ethnological Science. By Daniel Wilson.

76. Considerations upon the Evidences of the Early Voyages of the Scandinavians to this Country, and upon the Cosmical Myths supposed to relate to America. By A. C. Hamlin.

EXECUTIVE PROCEEDINGS

OF THE

ALBANY MEETING, 1856.

HISTORY OF THE MEETING.

The Tenth Meeting of the American Association for the Advancement of Science was held at Albany, N. Y., commencing on Wednesday, August 20, and continuing to Thursday noon, August 28.

The number of names registered in the book of members in attendance on this meeting is three hundred and eighty-one. Two hundred and six new members were chosen, of whom all but thirty-eight have already accepted their appointment, paying the assessment and signing the constitution. Thirty-one others have joined the Association by virtue of Rule 2 or 3. Seven others have paid, without a formal election, or signing the constitution. One hundred and forty-six papers were presented; most of which were read, but only a part have been printed. Some were thought unworthy of publication, and, in other cases, copies have not been furnished by their authors.

The sessions of the Association were held in the capitol of the State.

The meeting was opened by a prayer from Rev. William B. Sprague, D. D. Then the President, Professor James Hall, made the following Address: —

GENTLEMEN OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: — On taking the chair as President of this Association, I should do injustice to my own feelings were I not to express to you my sincere and heartfelt appreciation of your kindness and confidence in honoring me with your choice, — esteeming that expression of your regard both as a personal favor and as a tribute to the science in whose cause I am the earnest devotee and laborer. Left to myself I could never have assumed the position or its responsible duties; but your partiality almost makes me forget my own unfitness; — still I hesitate, as I am about to assume the obligations which have been so well and so ably discharged by those of my fellow members who have, with so much honor and dignity, filled this place.

To my friends around me I look for aid and counsel, for the right and impartial discharge of the duties devolving upon me; and to you, Gentlemen of the Association, I must appeal for that kind forbearance which may serve in some degree to render my duties less onerous, and my failures less embarrassing.

We have again met together after the usual interval, to compare the results of our labors in the service of Truth, — for Science is only another expression for the *true* in the Universe. We have come not only from all parts of the United States, but I see around me others who dwell amid different social and political surroundings. But here we all meet upon common ground, and with a common object in view.

Science recognizes no artificial boundaries, — the heavens present no civil or political divisions, — nor do the formations of the earth on which we stand recognize the limits of states or countries.

Is it strange, then, that we should forget artificial distinctions and divisions, in the pursuit of the great objects in which we are engaged, — each one viewing the labor of his fellows with that generous spirit which places it in its true position in the scale of merit.

We come together not to proclaim dogmas but to contribute our atoms of truth to the great fabric of Science. We have all gone back to the manifestations of the great Creator of the Universe for the study of those truths and those laws which were conceived by *one mind* and impressed by *one will* upon all created things.

The scintillations from yonder heavens, and the scarcely less brilliant gems of earth, tried by the laws of physics and of chemistry, will be displayed before us. The development of vitality and the problem

of life, in its past and its present phases, will not be the least interesting exhibition of our labors, and all these are to be woven together in one harmonious whole, to constitute our Science.

The title of our Association distinctly proclaims its objects. It is for the *advancement* of Science, and not for its diffusion, that we meet. It is in the hope of communicating new truths, and of adding something to the common stock of knowledge that we have associated ourselves.

To those, therefore, who are not of us, but who, nevertheless, honor us with their countenance and presence, we may excuse ourselves for making no popular display, and for discussing questions purely in their scientific relations.

But it is not to be understood from this, that our labors have no relation to the requirements of the active world around us; — scarcely an intelligent person, but must feel that Science has done much for human advancement.

It is no degradation to Science to put her hand to the plough, the loom, and the anvil, to speed the traveller on his way at such a rate that the term *travelling* will soon become obsolete, and to convey intelligence from man to man over wide distances even in advance of time itself.

All this and much more, which this occasion will not allow me to speak of, has Science done for practical life; — and in all this she has advanced civilization, — has promoted the comforts, the happiness, and well-being of mankind. Is she not, therefore, as a handmaid, worthy of your consideration, worthy of being recognized and inquired of by the recipients of her bounty, whether her convenience or welfare may not be promoted in some degree or in some manner, that she may the more rapidly advance those great objects and interests which lie at the foundation of modern civilization?

Before concluding I cannot forbear calling your attention to the circumstance that we are now assembled under the same roof where our Association in embryo first met, and where the true hearts and kindly spirits of some among our departed colleagues first held counsel upon the question, then momentous, whether American scientific men could be prevailed upon to unite in a harmonious confraternity for the advancement of their cause.

In yonder chamber, eighteen years ago, sat half a dozen men who

had just returned from the arduous field-labors of the year, and were comparing their observations one with another, and each one communicating freely new facts and new conclusions, for the harmonious working of the whole in a single science. This labor over, the question of inviting other laborers, in the same field of science, to join them in similar interchange of views, facts, and results, was discussed; on the one hand with sanguine hope, and on the other with timid doubt.

A second year the same parties were assembled in the same room, and around the same table, when the subject was again discussed, and what had before appeared desirable now seemed a pressing necessity, and it was decided to take some action.

The youngest member of that group, who felt himself too inexperienced to take any prominent part in these discussions, stands before you to advocate, not his own, but the merits of his colleagues; and, though the birth of the Association was proclaimed in a sister city, we claim for our own city the inception of the *Association of American Geologists*, of which our present *Association for the Advancement of Science* is the legitimate heir.

Gentlemen, again asking your attention not so much to the strict letter as to the spirit of our Constitution, I shall announce that our assembly is organized for the transaction of business.

At the conclusion of the President's address, the Hon. Amasa J. Parker, in behalf of the Local Committee and the citizens of Albany, welcomed the members of the Association in these words:—

MR. PRESIDENT AND GENTLEMEN OF THE ASSOCIATION:— As a member of the Local Committee, the agreeable duty has been devolved upon me of welcoming you, at this tenth annual meeting of the Association, to our State and city. We recur with pleasure to the fact that this is the second time we have been honored by your presence within the last five years; and we trust our city may be found so desirable a point for the sittings of the Association, with reference to its locality, its public institutions, the love of science, and the energetic devotion of many here to its interests, as to lead to its selection frequently hereafter as the place of meeting. We shall

always stand ready to extend to all its members and to all who are attracted to its meetings, as we now do, a most cordial welcome.

The hopes of science in this country centre in this Association. It embraces the most learned men, not only of our own country, but of the whole American continent. We are proud of the reputations of our men of science, already commanding the respect and admiration of the Old World. Who is not proud of the reputations of Henry, Silliman, Hall, and Bache? Who does not rejoice that the love of science of the great Franklin is continued in his descendants? Who is not proud of Peirce, Mitchel, and Dana, and the many others who are by no means to be considered as forgotten on an occasion like this because not specially named? Who does not rejoice that Agassiz, the great European Naturalist, was attracted to make our country his residence, as well by the congeniality of his associates here, as by the wide field afforded for scientific exploration?

We claim with pride our full share in the great scientific discoveries of the age. But we must never forget that science has no country, — that it is limited only by the Universe of God, — that it is but the development of truth which pervades all the works of the Creator, revealed to its votaries in proportion to the merit with which it is pursued, rewarding with its attainment, not only those who seek for knowledge for the intrinsic pleasure its acquisition affords, but blessing, in some form, the whole human race, by its benign aid to the advancement of agriculture, commerce, and manufactures. Science thus rewards all, by affording to some the highest mental enjoyment, and to others a vast increase of physical comforts.

In the spirit of this universality of science, and in the hope of promoting more extensively the objects of this Association, an effort was made to secure the attendance at this meeting, of many of the learned men of Europe. A general printed circular was addressed to the European *savans* last winter, from the Association; but the invitations from the Local Committee were not sent till June, in consequence of the delay incident to the correspondence with ship-owners and agents on both sides of the Atlantic. The owners of ocean steamers and packet ships promptly and most generously responded to the request of the Local Committee. More than thirty-five passages across the Atlantic both ways were placed at our disposal. These free passages were tendered only to those most eminent in science. Such men

could hardly be expected to leave their important positions and trusts on so short a notice. They all responded to our invitations most gratefully, and expressed an earnest desire to visit this country, and to attend upon the present occasion. It was expected, indeed, until very recently, that several distinguished foreigners would have honored us by their presence; but from various reasons they have been obliged reluctantly to decline. Liebig, for whose attendance Mr. Wadsworth had made so generous a provision, was compelled to decline the invitation on account of illness in his family. The meeting of the British Association for the Advancement of Science is at this time about being held, and doubtless prevented many of the learned men of England from attending here.

The Local Committee avail themselves of this occasion to express the great obligation they feel to the ship-owners and mercantile marine of the country for the great liberality they have evinced in promoting the objects of the present meeting in the manner before stated.

The Local Committee had thought it best to avail themselves of the presence of the Association to inaugurate two institutions; — the State Geological Hall and the Dudley Observatory. They had hoped that the vast geological collection of the State, for which we are so much indebted to your President, Professor Hall, would have been arranged and placed in the new building erected by the State for that purpose, in time for the present meeting; but the abrupt adjournment of the Legislature, without passing the supply bill, has prevented its completion and delayed the arrangement of the specimens. Meantime large additions to these collections are being made by the curator, Colonel Jewett, who is now in the field for that purpose.

The new instruments for the Dudley Observatory have been delayed, from unavoidable causes, much longer than was anticipated. The great Meridian Circle, now nearly finished at Berlin, will be here and mounted in a few weeks. The Transit Instrument is now finished and on its way. Both of these were, by the contract made by Dr. Gould, to have been delivered before the first of this month. The delay of the former was occasioned by a defect in the first casting of the axis.

The Observatory building has required enlarging for the reception of an instrument of so much larger size than was at first contemplated. The clocks, chronographs, barometers, thermometers, and magnetic apparatus have all been received, and will be open to your inspection.

The clocks, to give us time here during our meetings, are regulated by the instruments in the Observatory, and, when all our arrangements are perfected, will give time, if required, to all the railroads diverging from this city. The magnetic current from yonder hill can tick the time, correct to the tenth of a second, at Boston, Montreal, St. Louis, and New Orleans. Science shall thus point the way to secure to the works of man something of that system and order which pervade the works of God, and, in contributing largely to the business facilities of the age, shall lessen greatly the hazards of human life.

We acknowledge the great obligations which science and its votaries owe to the public press, and I am desired, in conclusion, for the purpose of securing accuracy in the published accounts of the proceedings of this Association, to request that the reporters who may attend the meetings from day to day, will submit their reports for correction to those who have taken part in the proceedings, before sending them to press. In no public proceedings can accuracy be more desirable, and more difficult to be secured by a spectator, than in matters of science.

In repeating the cordial greeting with which I am charged, I beg leave to assure the members of the Association of the pleasure their presence affords to our citizens, and of the sincere wish of the latter, that the visit of the former to our city may be made as agreeable to themselves as it will be useful to the great cause to which it will be devoted.

The Annual Address was not delivered by the retiring President, Professor Torrey, as he was unable to attend the meeting.

A Report on the Present State of our Knowledge of Linguistic Ethnology was read on Monday afternoon, August 25.

No lengthened abstract of the proceedings, scientific and executive, of the Albany Meeting of the Association is necessary in this place, as they are contained in full in the papers and resolutions printed in this volume.

The officers elected for the next meeting are Professor J. W. BAILEY, of West Point, President; Professor JOHN LECONTE, of Columbia, S. C., General Secretary; and Dr. A. L. ELWYN, of Philadelphia, Treasurer. The Permanent Secretary, Professor JOSEPH LOVERING, of Cambridge, was elected for a second term.

The Association voted to hold their next meeting at Montreal, Canada, on Wednesday, the 12th of August, 1857, having received an invitation to visit that city from prominent citizens.

During the session of the Association, the members and their ladies, besides receiving many private hospitalities, were elegantly entertained on Thursday evening, August 21, at the capitol, when the rooms of the State Library, which are connected with the capitol by a corridor, were thrown open to the inspection and enjoyment of the members; on Friday evening by Robert Townsend, Esq.; on Saturday evening by John V. L. Pruyn, Esq.; on Monday evening, in the new Geological Hall; on Tuesday afternoon by the venerable Mrs. Blandina Dudley, and on Tuesday evening by Hon. Franklin Townsend; on Wednesday evening, August 27, by Stephen Van Rensselaer, Esq., and on Thursday evening, August 28, by Edward C. Delevan, Esq.

Through the kindness and unwearied exertions of the Local Committee and other citizens of Albany, the Association received, individually and collectively, many attentions, and took pride and pleasure in acknowledging the same, as far as was in their power, by the votes of thanks which were unanimously passed at the close of the meeting, and which are printed in this volume.

During the meeting, a delegation consisting of Professors John W. Dawson and C. C. Smallwood, Rev. J. Flanagan, Dr. Thomas W. Jones, A. N. Rennie, Esq., Sir William E. Logan, H. Barnston, Esq., and Dr. Slingston, appeared as a delegation from Canada, and presented an invitation, in behalf of the city of Montreal and the Natural History Society of that city, to the Association to hold its next meeting in Montreal.

Dr. Steiner offered an invitation in behalf of the Maryland Institute and citizens of Baltimore, that the Association should hold its next meeting in that city.

The following invitation was also received from Springfield: —

Commonwealth of Massachusetts. City of Springfield. In the year one thousand eight hundred and fifty-six.

Resolved, That the City Council of the city of Springfield, hereby

tender to the American Association for the Advancement of Science, the use of the City Hall and other public rooms; and respectfully invite them to hold their next annual meeting in Springfield.

Resolved, That the City Clerk forward to said Association now in session at Albany an attested copy of these resolutions.

In Board of Aldermen, August 22, 1856. Read, passed, and sent down. JOSEPH INGRAHAM, Clerk.

Common Council, August 25, 1856. Read and passed.
C. C. CHAPIN, Clerk.

A true copy. Also, a true copy of record.
Attest. JOSEPH INGRAHAM,
City Clerk of Springfield, Mass.

RESOLUTIONS ADOPTED.

Resolved, That the Sectional Committee be held responsible for the character of the communications admitted, and for that of those authorized to be published in the Proceedings.

Resolved, That the Chairman of the Sections be requested to notify members that strict adherence is expected to the time named for the reading of their papers, and that they be requested to close the communications at the expiration of the time so specified.

Resolved, That the time occupied in the discussion of any paper shall not, unless by a special vote of the Section, exceed one half of the time allowed for the reading of the paper.

Resolved, That the limit of time allowed to papers, entered without specification of the time required, be twenty minutes.

Resolved, That Dr. Blotchford, the representative of the American Medical Association, as a substitute for Dr. Pitcher, be presented to the Association for the Advancement of Science.

Resolved, That a delegation be appointed to represent this Association in the West at the next meeting of the American Medical Association.

Resolved, That for the remainder of the present session, the provisions of the old Constitution be continued in force, and that the Revised Constitution go into effect at the opening of the next meeting.

Resolved, That the Vice-President for the next meeting be appointed at the present meeting, according to the forms of the old constitution as applied to the other General Officers.

Resolved, That Professor Haldeman's Report be printed, and two hundred and fifty copies placed at his disposal; and that he be requested to continue his researches in Linguistic Ethnology, with a view to report a system of notation for American and exotic Languages.

Resolved, That the papers read at this meeting be referred to the Standing Committee, to determine in reference to their publication, and that the papers not accepted for publication be returned to their authors.

Resolved, That the Permanent Secretary be allowed to put the Proceedings of the Albany meeting to press one month after the adjournment of the Association, and that one thousand five hundred copies be printed.

Resolved, That the Standing Committee be authorized to extend an invitation to Foreign Learned Societies to attend the Annual Meetings of the Association.

Resolved, That volume nine of Proceedings be presented to the State Library of New York; that volumes six, seven, eight, nine, and ten, be presented to the Athenæum of Nantucket, and the tenth volume to those gentlemen of Albany, not members, who have contributed to the funds of the Association; and volumes seven, eight, and nine to Mr. Horton, in consideration of his services as Assistant Local Secretary.

A request from P. J. O. Chauveau, Superintendent of Education for Lower Canada, that two copies of the Proceedings be furnished him, one for the Normal School, and the other for the Library of Superintendence, was referred to the Permanent Secretary, with power to give such volumes as were not scarce.

Resolved, That the Standing Committee be authorized to act for the Association in any matters of business which may not have been completed at the time of the adjournment of the Albany meeting.

Resolved, That the salary of the Permanent Secretary be increased to $500 a year.

Resolved, That the use of the Hall be granted to Dr. Hare, after the adjournment of the Association.

Resolved, That whereas the American Association for the Advancement of Science regard the full and thorough geological survey of the State of Ohio as highly important in a scientific, as well as economic point of view, the following persons be appointed a Committee to memorialize the Legislature of that State during its session in the coming winter, to make a just and liberal appropriation to carry forward the work of such geological survey. [This committee is printed in the first part of the volume, p. viii.]

Resolved, That a Special Committee of five be appointed to investigate the principles which render precious metals current, as moneys, — to promote the establishment of a simple and uniform system in the Mints of the United States, — and to invite a general conformity in the coinage standards of other nations. [Referred to the Committee on Weights, Measures, and Coinage.]

Professor C. Dewey remarked: "Some of you are familiar with the famous fir-trees of California, the *Abils Donglassei*. These trees, some of which are thirty feet in diameter, are supposed to be upwards of three thousand years old. The attention of the Association is called to the fact that these trees are being exterminated as the settlement of the country advances. But twenty-five of them, we are informed, are now left standing in the States, and they are not to be found but in one place. It is believed that an expression of interest in their preservation by the Association, made in the right quarter, would save the residue of these gigantic inhabitants of our primitive forests from destruction."

Resolved, That this matter be referred to Professor Henry, of the Smithsonian Institution, with the request that he will correspond, in behalf of this Association, with the authorities of California or at Washington, in relation to the preservation of these trees; or take such other course as may seem more effective.

The following resolutions were adopted in relation to the letter of Mayor Wood of New York, concerning a University in that city: —

Resolved, That the Advancement of Science, which forms the great object of this Association, requires also the establishment of Universities, where all branches of human knowledge may be pursued, under eminent Professors, to their last development.

Resolved, That the establishment of at least one such institution in any part of our country at the present time is an object of the highest

interest to this Association, and would, in their judgment, form an epoch in the progress of science in this country.

Resolved, That every judicious effort made for the accomplishment of this great work will receive our hearty commendation and firm support.

Resolved, That we consider the recommendation before us as such an effort as is referred to in the last resolution.

VOTES OF THANKS.

Resolved, That the Association returns its thanks to the Maryland Institute, who have so kindly invited us to assemble in their city, and expresses the hope that in some future year the Association may be able to meet their wishes.

Resolved, That the Association returns its thanks to the Mayor and Council of Springfield, for their invitation to meet in their city, and regret that they cannot accept it for the next summer.

Resolved, That the thanks of the Association be tendered to Professor Hall and Mr. Palmer, who have so kindly opened their collection for the inspection of members.

Resolved, That the heartiest thanks are due by the Association, and by every member of it, to the Local Committee for their admirable arrangements for the meeting, and their unremitting and most kind attentions during the progress of the session.

Resolved, That the thanks of the Association be tendered to the Directors of these railroads: New York Central; Michigan Central; Western; Hartford and New Haven; Baltimore and Ohio; Pennsylvania; Philadelphia, Wilmington, and Baltimore, and of the steamer Alida, and the steamships from New York to New Orleans, for the free return tickets which have been offered to members in attendance at this meeting.

Resolved, That the thanks of the American Association be presented to the Directors of the Cunard line of steam-packets, and especially to Mr. Edward Cunard, for the very prompt and generous manner in which the free passages were tendered by these lines for scientific gentlemen from Europe who might desire to attend this meeting; and that

similar thanks be offered to the Directors of the Bremen line, of the Glasgow Steamship Company, of the Collins line, and of the Belgian line, for similar acts of generosity.

Resolved, That thanks be returned to Messrs. E. C. Morgan, Mortimer Livingston, Cornelius Grinnell, Spofford, Tileston & Co., and Grinnell, Minturn & Co., for the generous offer of free passages in the sailing packets belonging to them.

Resolved, That, in the words of a distinguished foreigner to the Local Committee, such acts exalt the commerce of America, and place it at the head of the commerce of the civilized world.

Resolved, That the thanks of the Association be tendered to the Trustees or Directors of the State Library; Dudley Observatory; Albany Academy and Institute; Medical College; Albany Hospital; Geological Hall, Agricultural Rooms, and Collections; New York State Agricultural Society; Female Academy; Penitentiary; Albany Rural Cemetery, for the invitations which have been extended to its members, and the many facilities offered for inspection.

Resolved, That the sincere thanks of the Association be returned to the Legislature of New York and the Trustees of the Capitol, for the ample accommodations which have been afforded for the meeting of the Association, its Secretaries, and Committees.

Resolved, That the thanks of the Association be presented to the President of the Mechanics and Farmers Bank for his generosity in negotiating the funds of the Association.

Resolved, That our very warm thanks are returned to the citizens and ladies of Albany, who have, with such unbounded hospitality, opened their hearts and dwellings to the reception of the members of the Association during this meeting, and that our best wishes attend them now and will remain with them through our lives.

The following remarks were made by Rev. Dr. Ferris: —

The interval since this Association met last in this city is short, and yet, on our assembling, we find not among us the genial friend — the ripe scholar — the true man — the man of science, Dr. T. Romeyn Beck. It has pleased an allwise Providence that he should be carried to the house appointed for all the living. It was my privilege to know well four of the Becks — brothers.

The Adjutant-General, Nicholas, passed away many years since, ere he had accomplished what an earnest mind promised. All know how Dr. John B. Beck graced the medical profession, and won for himself universal respect and admiration as a Professor in the College of Surgeons and Physicians of New York; of Dr. Lewis C. Beck the State of New York has an abiding memento in the results of the Scientific Survey of the State, as will be seen in the collections of the State cabinet. His works on Chemistry and Botany have been the guides of many an inquirer, and his labors in his favorite department in Rutgers College will never be forgotten.

Dr. T. Romeyn Beck, — as a most successful educator — as an indefatigable laborer in various branches of learning — as the author of the first American work on Medical Jurisprudence (I think), which has become a standard in that department, and been translated and used abroad, and as a Professor of a Medical Institute for many years, — has occupied a place granted to very few. He became, in 1817, the Principal of the Boys' Academy, whose edifice you have all admired in the Park opposite, an institution which received new life under his energy, and which has yielded to the various walks of life a very large number of most able men, and where (I believe I do not mistake), in connection with Dr. Beck, our esteemed associate of the Smithsonian, whose reputation is world wide, received his first impulse in those researches which have so distinguished him. Here Dr. Beck continued for over twenty years; and, while here engaged, was conducting special chemical instruction, and was lecturer in the Medical College then at Fairfield. He was the most industrious man in scientific labors I have known, — apparently never tiring, and never confused by the number or variety of his pursuits. He was eminently a man of system, and to this must be attributed his ability to accomplish so much. One of the choicest heirlooms must have been his volumes of Common Places, the gatherings of a most laborious life. In all enterprises undertaken here for science or literature, his was an active part. The circle of his friends was large, and among educated men especially. His latter years were occupied as Secretary of the Regents of the University of the State of New York — a most important and responsible office — and in the prosecution of science. He has by no means lived in vain. Having reached a full measure of years, he has gone

to his rest; but his memorial is in many hearts. Albany city and New York State have reason to note it in imperishable record, that he was theirs.

We love to trace influences to their sources, to inquire whence all this? It is enough to say that this quartette of brothers had a mother worthy a place above hers of the Gracchi. Think of her, as when, advanced beyond the common lot of life, she was coadjutor and reliance in the meteorological observations taken at the Albany Academy for many years.

Mr. President, — As our friend has gone, so we are going; this may be the last meeting to some of us; — may ours be a full preparation for it, such a preparation as true religion secures.

I beg to offer the following resolutions: —

Resolved, That this Association record, with feelings of regret, the removal by death of T. Romeyn Beck, M. D., L L. D., of the city of Albany, since its last meeting in this place.

Resolved, That the scholar-like attainments of our associate in various departments of Science and Literature, and his long and successful devotion to the interests of learning, his distinguished ability and his profound worth have given him a high place among the sons of Science, and the benefactors of man; and the memory of such should be fondly cherished.

REPORT OF THE PERMANENT SECRETARY.*

The duties of the Permanent Secretary during the last year have been nearly doubled in consequence of the re-publication of the Cleveland volume, the charge of which was committed to his hands. The preparation of the Proceedings of the Cleveland and Providence meetings for the press, the examination of proof-sheets, the distribution of the volumes when printed, and the making of contracts and payment of bills connected with these matters, constitute the most onerous part of the labor performed by the Permanent Secretary. The Cleveland and Providence volumes were published in April, and have been, as far as practicable, distributed to members entitled to receive them. Also circulars have been sent as follows: —

1st, To newly elected members.

2d, To members, calling on them for papers to be printed.

3d, To members, informing them that the volumes of Proceedings were ready.

4th, To members, informing them that volumes had been sent.

5th, To delinquent members.

6th, To members who have paid assessments and wish receipts.

Since August 25, 1855, when the Permanent Secretary made his last Report, down to August 20, 1856, the date of the present report, $960.50 have been collected by the Permanent Secretary, mostly in the form of assessments, but partly by the sale of the Proceedings of the Association. If to the above-named sum are added $291.92, received from members directly by the Treasurer, and $1,186.54 received by the Treasurer from members through the Permanent Secretary, an aggregate collection of $2,438.92 results. The Permanent Secretary has also received a balance of $333, subscribed at Provi-

* In the Providence volume, page 298, line 7, instead of "eighty-six dollars," read seventy-six, which corresponds with the statement on the preceding page of the same volume, 5th line from bottom. On line 8 of same page, for "thirty dollars," read twenty dollars. On line 11 of same page, for "eight hundred and seventeen dollars," read seven hundred and ninety-seven dollars. On page 299, lines 21 and 22, for "sixty-eight dollars and thirty-three cents," read forty dollars and sixty-eight cents. These numerical errors exist only in the *printed* Reports, and the numbers, as corrected, correspond to the manuscript Reports.

dence, from the Local Committee of that city, to assist in the publication of the Proceedings of the Providence meeting, and from G. P. Putnam & Co. $11.29, for the sale of Proceedings. The grand total amounts to $2,783.21.

The expenses since the last account rendered (which is printed in the volume of Proceedings at Providence, pages 304 and 305), have amounted to $2,647.69. This sum exceeds the average annual expenses by about $1,000. The excess has been caused by the reprint of the volume of Cleveland Proceedings. The total expenditure of $2,647.69 may be divided as follows: —

For the preparation and publication of vols. VII. and IX.	$2,201 00
Salary of Permanent Secretary	300 00
Postage	45 80
Printing and sending of circulars	25 72
Sundries	70 67
Discount on distant banks	4 50
Total	$2,647 69

If the expenses (or $2,647.69) are subtracted from the income of the Association (or $2,783.21), we have a balance above expenditure, of $135.52. This is to be added to the balance of last year, which was $111.96 in the hands of the Permanent Secretary, and $620.58 in the hands of the Treasurer. The present balance is $868.06, of which $106.31 is in the hands of the Permanent Secretary, and $761.77 in the hands of the Treasurer.

The Permanent Secretary states that, in conformity with the enactments of the Association, and the notice given by him last year to the Standing Committee, he has struck from the list of names those, and those only, from whom no dues have been received since the last Albany Meeting, in 1851. Whereas 91 new members were added at Providence, 492 have been struck out since that meeting, the number of members being reduced from 1,023, as before the Providence Meeting, to 622, as at the beginning of this meeting. As each person so struck from the list of members is now indebted to the Association for $12, this repudiation of assessments makes a loss of funds to the Association, of $5,904.

It should be added that several of those struck out have since paid the $12 due, and will be restored to their places in the next volume.

REPORT OF THE AUDITORS.

We have examined the accounts of the Treasurer and Permanent Secretary, and find them correct; and the balances in their hands to the credit of the Association stated in the preceding Report of the Permanent Secretary, to wit: —

In the hands of the Permanent Secretary, . . .	$106.31
" " " Treasurer, ...	790.20
	$896.51

Signed JOHN L. LECONTE, J. H. C. COFFIN, } *Auditors.*

American Institutions receiving Copies of the Proceedings of the American Association, by Vote of the Association.

	Volumes VII.	VIII.	IX.
American Academy, *Boston*, ...	"		"
Natural History Society, *Boston*, ...	"		"
New York Lyceum, *New York*, ...		"	
Philadelphia Academy of Natural Sciences, *Philadelphia*,	"	"	"
American Philosophical Society, ...	"	"	"
Western Academy of Natural Sciences, *Cincinnati*, .	"		"
Cleveland Academy of Natural Sciences, *Cleveland*, .	"	"	"
Smithsonian Institution, *Washington*, ...	"		"

List of European Institutions to which Copies of the Proceedings of the American Association were distributed by the Permanent Secretary in 1856.

	Volumes.				
	II.	IV.	VII.	VIII	IX.
Stockholm, — Kongliga Svenska Vetenskaps Akademien,			*	*	*
Copenhagen, — Kongel. danske Vidensk. Selskab,			*	*	*
Moscow, — Soc. Imp. des Naturalistes,			*	*	*
St. Petersburg, — Acad. Imp. des Sciences,			*	*	*
" " Kais. Russ. Min. Gesellsch.,			*	*	*
Amsterdam, — Acad. Royale des Sciences,			*	*	*
Haarlem, — Holl. Maatschappij der Wettenschappen,	*		*	*	*
Berlin, — K. P. Akad. der Wiss.,			*	*	*
Breslau, — K. L. C. Akad. der Naturf.,			*	*	*
Franckfurt, — Senckenbergische Gesellschaft,			*	*	*
Göttingen, — Königl. Gesellschaft der Wiss.,			*	*	*
Munich, — K. B. Akad. der Wiss.,			*	*	*
Prag, — K. Böhm. Gesellschaft der Wiss.,			*	*	*
Vienna, — K. Akad. der Wiss.,		*	*	*	*
Bern, — Allg. Schw. Gesellschaft,			*	*	*
Geneve, — Soc. de Physique et d'Hist. Nat.,			*	*	*
Bruxelles, — Acad. Royale des Sciences,			*	*	*
Liège, — Soc. Royale des Sciences,			*	*	*
Paris, — Institut de France,			*	*	*
Turin, — Accademia Reale delle Scienze,			*	*	*
Madrid, — Real Acad. des Ciencias,			*	*	*
Cambridge, — Camb. Philosophical Society,			*	*	*
Dublin, — Royal Irish Academy,			*	*	*
Edinburgh, — Royal Society,			*	*	*
London, — Board of Admiralty,			*	*	*
" East India Company,			*	*	*
" Museum of Practical Geology,			*	*	*
" Royal Society,			*	*	*
	1	1	28	28	28

CASH ACCOUNT OF THE

Dr. AMERICAN ASSOCIATION in

Metcalf & Co., Printers,	$8.00
Expenses at Providence,	50.00
Brainerd & Burridge, for rejected map in VIIth volume,	37.50
Metcalf & Co., for printing blank bills,	5.67
Assistant local secretaries at Providence,	15.00
Rice & Kendall, for paper,	579.52
Binding volume of Washington Proceedings,	158.25
Metcalf & Co., for printing VIIth and IXth volumes,	890.98
Lemon, for binding VIIth and IXth volumes,	159.82
Duval, for printing plates,	99.00
Bradford, for printing and engraving plates,	63.00
Bien, for printing plates,	100.00
Moore & Crosby, for printing plate,	20.00
Kilburn & Mallory, for wood-cuts,	30.00
Index for Cleveland and Providence volumes,	10.00
Binding extra copies of Addresses of Dana and Gibbs,	4.06
Circulars to delinquents, etc. etc.,	20.00
Engraved circular to eminent foreigners,	5.72
William Mills, services in distributing volumes,	18.37
Express,	22.50
Postage,	45.80
Discount on distant banks,	4.50
Salary of Permanent Secretary,	300.00
	$2,647.69
Balance to next account,	106.31
	$2,754.00

PERMANENT SECRETARY.

Account with JOSEPH LOVERING. Cr.

Balance from last account,	$111.96
Salary of Permanent Secretary,	300.00
Cash from Treasurer,	1037.25
Cash from Local Committee at Providence,	333.00
G. P. Putnam & Co. sale of Proceedings,	11.29
Assessments from August 21, 1855, to August 20, 1856,	960.50
	$2,754.00

We certify that we have examined the preceding account of the Permanent Secretary, comparing the credits with the Treasurer's account, and the receipt book, and the debits with the several vouchers, and find the whole correct; and the balance of one hundred and six dollars and thirty one cents, properly credited in the next account.

JOHN L. LECONTE,
J. H. C. COFFIN, } *Auditors.*

ALBANY, August 27, 1856.

REPORT OF THE TREASURER.

The Treasurer received at Providence from the Permanent Secretary, eleven hundred and ninety-seven dollars and fifty cents, collected by him from members. He has received himself from members, since his last report, two hundred and ninety-one dollars and ninety-two cents.

He has paid to the Permanent Secretary, his salary of three hundred dollars: to J. Bien, for Plates, sixty dollars; to Edward Wharter, thirty dollars and seventy-five cents; and to the Permanent Secretary, nine hundred and fifty-six dollars. These expenditures, amounting to thirteen hundred and forty-six dollars and seventy-five cents, taken from the receipts of fourteen hundred and eighty-nine dollars and forty-two cents, leave a balance of one hundred and forty-two dollars and sixty-seven cents, which, added to the balance of last year, (of six hundred and forty-nine dollars and three cents,) makes a total balance of seven hundred and ninety-one dollars and seventy cents.

A. L. ELWYN, *Treasurer.*

REPORT OF THE AUDITORS.

We have examined the preceding account of the Treasurer, comparing the debits with the account of the Permanent Secretary, and find a difference of $1.50 in favor of the Secretary; and with this correction, that the balance in the hands of the Treasurer to the credit of the Association should be $790.20 instead of $791.70.

No detailed accounts are presented of the money received from members, nor any prior statement of the balance on hand last year. We believe them, however, to be correct.

JOHN L. LECONTE,
J. H. C. COFFIN, } *Auditors.*

CORRESPONDENCE.

November 1, 1855.

Sir, — We have the honor to inform you that the Tenth Meeting of the American Association for the Advancement of Science will be held in the city of Albany, commencing its sittings on Wednesday, August 20, 1856, and continuing during such time, not less than a week, as may be then decided.

It is anticipated that the Dudley Observatory and the Geological Museum will be inaugurated during the meeting, upon days to be set apart for the purpose, and it is also proposed that excursions be made to points of scientific and historical interest in the vicinity.

We are directed by the Association to solicit the honor of your presence on the occasion, and the Local Committee have instructed us to assure you of an earnest and cordial welcome. Permit us to hope that you will favor the Association by transmitting an affirmative reply to the General Secretary at Cambridge, Mass., or to the Local Committee at Albany, N. Y.

We have the honor to be, Sir, very respectfully yours,

JAMES HALL, *President.*
JOSEPH LOVERING, *Permanent Secretary.*
B. A. GOULD, JR., *General Secretary.*

T. ROMEYN BECK,
THOMAS W. OLCOTT,
JAMES H. ARMSBY,
} *For the Local Committee.*

Past Meetings of the Association.

1. Philadelphia, Pa.,	1848,	W. C. Redfield, *President.*
2. Cambridge, Mass.,	1849,	Joseph Henry, "
3. Charleston, S. C.,	1850,	" "
4. New Haven, Ct.,	1850,	A. D. Bache, "
5. Cincinnati, O.,	1851,	" "
6. Albany, N. Y.,	1851,	Louis Agassiz, "
7. Cleveland, O.,	1853,	Benjamin Peirce, "
8. Washington, D. C.,	1854,	James D. Dana, "
9. Providence, R. I.,	1855,	John Torrey, "

INDEX.

A.

Acanthocephala, on the digestive apparatus of the. David F. Weinland, II. 197.
Acoustics, on, applied to public buildings. Joseph Henry, I. 119.
Address, by Hon. Amasa J. Parker, II. 232.
———, opening, of the President, II. 230.
Agency, on the, of the Gulf-Stream in the formation of the Peninsula of Florida. Joseph Le Conte, II. 103.
Albany Meeting, executive proceedings of the, 1856. II. 229.
Ammonia in the Atmosphere. E. N. Horsford, I. 145.
Animals, on the names of, with reference to the origin of languages. David F. Weinland, II. 193.
Archimedes, observations on the genus, or Fenestella, with descriptions of species, &c. James Hall, II. 176.
Artesian Wells, statistics of some, of Alabama. A. Winchell, II. 94.
Atmosphere, on the peculiar appearance of the, on the 23d of May, 1856, I. 237.
Auditors, Report of, on account of Permanent Secretary, II. 246.
———, Report of, on Treasurer's account, II. 252.

B.

Bache, A. D. Approximate cotidal lines of diurnal and semi-diurnal tides of the Coast of the United States on the Gulf of Mexico, I. 153.
——— Notes on the progress made in the Coast Survey, in prediction tables for the tides of the United States Coast, I. 166.
——— Notice of observations to determine the progress of the tidal wave of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments, I. 173.
——— Observations to determine the cause of the increase of Sandy Hook, made by the Coast Survey for the Commissioners on Harbor Encroachments of New York, I. 171.
——— On the general distribution of terrestrial magnetism in the United States, from observations made in the United States Coast Survey, and others, I. 187.
Barometer, on the sulphuric-acid. Joseph Henry, I. 135.
Batrachian reptile, on a, from the coal formation. Jeffries Wyman, II. 172.
Beck, Dr. T. Romeyn, notice and resolutions in honor of, II. 241.
Blake, William P. Observations on the orography of the Western portion of the United States, II. 119.
Boundary, general description of the country adjacent to the, between the United States and Mexico. W. H. Emory, II. 134.
Broadtop Coal Basin, on the, in Central Pennsylvania. J. P. Lesley, II. 78.
Brocklesby, John. Some experiments on visual direction, I. 139.

C.

Carboniferous Limestones, on the, of the Mississippi Valley. James Hall, II. 51.
Causation, investigation and calculation of the results of a process of. John Patterson, I. 29.
Cause of the increase of Sandy Hook, observations to determine the, made by the Coast Survey for the Commissioners on Harbor Encroachments of New York. A. D. Bache, I. 171.
Celestial Arcs, on a new method of measuring. Alvan Clark, I. 108.
Chauvenet, W. A simple method of correcting the common nautical method of "Double Altitudes" of the sun, moon, or a planet, for the change of declination between the observations, I. 101.
——— On a method of determining the latitude of a place from the observed times when two known stars arrive at the same altitude, I. 103.
Clark, Alvan. On a new method of measuring celestial arcs, I. 108.
Coal-Basin, on the Broadtop, in Pennsylvania. J. P. Lesley, II. 78.
Coast Survey, notes on the progress made in the, in prediction tables for the tides of the United States. A. D. Bache, I. 166.
Committees, Special, ix.

Committee, Standing, viii.
Constitution of the Association, xiii.
Co-tidal Lines, approximate, of diurnal and semi-diurnal tides of the Coast of the United States, on the Gulf of Mexico. A. D. Bache, I. 153.
Correspondence, II. 253.
Cyclones, on the avoidance of the violent portions of, I. 222.
———, on the, of the North Pacific Ocean, I. 214.

D.

Dana, James D. Plan of development in the geological history of North America, II. 1.
Dawson, J. W. On the parallelism of the rock formations of Nova Scotia with those of other parts of America, II. 18.
——— Remarks on a specimen of fossil wood from the Devonian rocks of Gaspe, Canada East, II. 174.
Delegation from Montreal, II. 236.
Dewey, Prof. C. Remarks of, II. 239.
Digestive Apparatus, on the, of the Acanthocephala. David F. Weinland, II. 197.
"*Double Altitudes*," a simple method of correcting the common nautical method of, of the sun, moon, or a planet, for the change of declination between the observations. W. Chauvenet, I. 101.
Dudley Observatory, on the meridian instruments of the. B. A. Gould, I. 113.

E.

Efflorescence from Brick Masonry. E. B. Hunt, II. 216.
Elephant, notes on the teeth of an, discovered near Zanesville, Ohio. J. Wyman, II. 169.
Elliott, E. B. Vital statistics, I. 50.
Elwyn, Dr. A. L., Treasurer's report of, II. 252.
Emory, W. H. General description of the country adjacent to the boundary between the United States and Mexico, II. 134.
Ethnology, linguistic, report on the present state of our knowledge of. S. S. Haldeman, I. 1.
Executive Proceedings of the Albany Meeting, 1856, II. 229.

F.

Fossil Elephant, on the geological position of the deposits in which occur the remains of the, of North America. J. W. Foster, II. 148.
Fossil Fishes, on the relations of the, of the sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic periods. W. C. Redfield, II. 180.
Fossil Wood, remarks on a specimen of, from the Devonian rocks of Gaspe, Canada East. J. W. Dawson, II. 174.
Foster, J. W. On the geological position of the deposits in which occur the remains of the fossil elephant of North America, II. 148.

G.

Geological History, plan of development in the, of North America. James D. Dana, II. 1.
Geological observations on the Pluto-volcanic slope of the Sierra Madre along the Azimuth Boundary line through Northwest Sonora. Arthur Schott, II. 25.
Geology, notes on the, of Middle and Southern Alabama. A. Winchell, II. 82.
Gibbes, L. R. Remarks on Niagara Falls, II. 69.
Gould, B. A. On the meridian instruments of the Dudley Observatory, I. 113.

H.

Haldeman, S. S. On the relations between Chinese and the Indo-European languages, II. 201.
——— Report on the present state of our knowledge of linguistic ethnology, I. 1.
Hall, James. Observations on the genus Archimedes, or Fenestella, with descriptions of species, etc., II. 176.
——— On the carboniferous limestones of the Mississippi Valley, II. 51.
——— President, opening address by, II. 230.
Hamlin, A. C. Supposed Runic Inscriptions, II. 214.
Harris, Rev. Mr. Notice of Dr. T. Romeyn Beck, II. 241.
Henry, Joseph. On acoustics applied to public buildings, I. 119.
——— On the sulphuric-acid barometer, I. 135.
History of the Albany Meeting, 1856, II. 229.
Horsford, E. N. Ammonia in the atmosphere, I. 145.
Hospitalities extended to the Association, II. 236.
Hough, Franklin B. Results of meteorological observations made at New York academies, I. 231.
Human Mortality, on the laws of. C. F. M'Cay, I. 21.
Hunt, E. B. On efflorescence from brick masonry, II. 216.
——— On systematizing the abbreviations of titles of periodicals, translations, &c., II. 218.

I.

Inscriptions, supposed Runic. A. C. Hamlin, II. 214.
Institutions receiving Proceedings, II. 246.
Invitation from Baltimore, II. 236.
——— from Montreal, II. 236.
——— from Springfield, II. 236.

L.

Languages, on the names of animals and plants with reference to the origin of, and to the countries where nations passed their childhood. David F. Weinland, II. 193.

———, on the relations between Chinese and the Indo-European. S. S. Haldeman, II. 201.

Latitude, on a method of determining the, from the observed times when two known stars arrive at the same altitude. W. Chauvenet, I. 103.

Le Conte, Joseph. On the agency of the Gulf-Stream in the formation of the Peninsula of Florida, II. 103.

Lesley, J. P. On the Broadtop Coal Basin in Pennsylvania, II. 78.

Lithium, redetermination of the atomic weight of. J. W. Mallet, I. 144.

Local Committee, address in behalf of, II. 232.

Lovering, J., Permanent Secretary, report of, II. 244.

——— Cash account of, II. 248.

——— Stock account of, II. 250.

M.

Mallet, J. W. Redetermination of the atomic weight of Lithium, I. 144.

Masonry, on efflorescence from brick. E. B. Hunt, II. 216.

Mathematics and Physics, list of papers read, but not published, II. 222.

M' Cay, C. F. On the laws of human mortality, I. 21.

Measuring Celestial Arcs, on a new method of. Alvan Clark, I. 108.

Meeting, Albany, executive proceedings of, II. 229.

———, Montreal, officers for, II. 235.

———, next, at Montreal, II. 236.

Meetings of the Association, xii.

Members elected at the Albany meeting, xlvi.

Members of the Association, xxiii.

Meridian Instruments, on the, of the Dudley Observatory. B. A. Gould, I. 113.

Meteorological Observations, results of, at New York academies, from 1826 to 1850, I. 231.

Monsoons, I. 215.

Montreal, Delegation from, II. 236.

——— meeting, officers for, II. 235.

N.

Names, on the, of animals and plants, with reference to the origin of languages, and to the countries where nations passed their childhood. David F. Weinland, II. 193.

Natural History, titles of papers read, but not published, II. 226.

Niagara Falls, remarks on. L. R. Gibbes, II. 69.

O.

Officers at the Albany Meeting, viii.

Officers for the Montreal Meeting, xi. and II. 235.

Orography, observations on the, of the Western portion of the United States. William P. Blake, II. 119.

P.

Papers, presented, but not published, II. 222.

Parallelism, on the, of the rock formations of Nova Scotia with those of other parts of America. J. W. Dawson, II. 18.

Parker, Hon. Amasa J., address by, II. 232.

Paterson, John. Investigation and calculation of the results of a process of causation, I. 29.

Peninsula of Florida, on the agency of the Gulf-Stream in the formation of the. Joseph Le Conte, II. 103.

Plants, on the names of, with reference to the origin of languages. David F. Weinland, II. 193.

Proceedings distributed to European Institutions, II. 247.

———, executive, of the Albany meeting, II. 229.

——— voted to American Institutions, II. 246.

Progress made in the Coast Survey in Prediction Tables, notes on, for the tides of the United States Coast. A. D. Bache, I. 166.

Progress of the Tidal Wave, notice of observations to determine the, of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments. A. D. Bache, I. 173.

Putnam, G. P. & Co., account of, II. 251.

R.

Redfield, W. C. On the relations of the fossil fishes of the sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic periods, II. 180.

——— On the spirality of motion in whirlwinds and tornadoes, I. 212.

——— On various cyclones or typhoons of the North Pacific Ocean, I. 214.

Report of Auditors, on account of Permanent Secretary, II. 246.

——— on Treasurer's account, II. 252.

——— of Dr. A. L. Elwyn, Treasurer, II. 252.

——— of Joseph Lovering, Permanent Secretary, II. 244.

——— on the present state of our knowledge of linguistic ethnology, I. 1.

Reports on the state of science to be made, xxi.

Resolutions adopted, II. 237.

Resolutions and Enactments of a permanent character, xx.

Rock Formations, on the parallelism of the, of Nova Scotia with those of other parts of America. J. W. Dawson, II. 18.

Rodgers, John. On the avoidance of the violent portions of cyclones, I. 222.

S.

Sandy Hook, observations to determine the cause of the increase of, I. 171.
Satellites, the stability of, revolving in small orbits. Daniel Vaughan, I. 111.
Schott, Arthur. Geological observations on the Pluto-volcanic slope of the Sierra Madre along the Azimuth Boundary line through Northwest Sonora, II. 25.
Schott, Charles A. Discussion of the secular variation of the magnetic inclination in the Northeastern States, I. 177.
——— Supplement to the paper on the "Secular Variation in the Magnetic Declination on the Atlantic and Gulf Coast of the United States, from Observations in the 17th, 18th, and 19th centuries," published in the Providence Proceedings of the Association, I. 173.
Secretary, Permanent, cash account of, II. 248.
———, report of, II. 244.
———, stock account of, II. 250.
Secular variation of the magnetic inclination, discussion of the, in the Northeastern States. Charles A. Schott, I. 177.
Smallwood, Charles. On the peculiar appearance of the atmosphere on the 23d of May, at St. Martin's, Isle Jesus, Canada East, I. 237.
Spirality of Motion, on the, in whirlwinds and tornadoes. W. C. Redfield, I. 212.
Springfield, invitation from, II. 236.
Stock, balance of, II. 251.
Storms, universality of the law of, I. 216.
Supplement to the paper on the "Secular Variation in the Magnetic Declination on the Atlantic and Gulf Coast of the United States, from Observations in the 17th, 18th, and 19th centuries," published in the Providence Proceedings of the Association. Charles A. Schott, I. 173.

T.

Table of Contents, III.
Terrestrial Magnetism, on the general distribution of, in the United States, from observations made in the United States Coast Survey, and others. A. D. Bache and J. E. Hilgard, I. 187.
Thanks, votes of, II. 240.
Tidal Wave of the Hudson River, notice of observations to determine the progress of. A. D. Bache, I. 173.
Tides, approximate co-tidal lines of diurnal and semi-diurnal, of the Coast of the United States on the Gulf of Mexico. A. D. Bache, I. 153.
———, notes made in the Coast Survey, on the progress in prediction tables for the, of the United States Coast. A. D. Bache, I. 166.
Titles of papers read, but not published, II. 222.
——— of periodicals, translations, &c., on systematizing the abbreviations of, II. 218.
Treasurer, report of, II. 252.
Typhoon, notice of a, at the Bonin Islands, I. 222.
Typhoons, on the, of the North Pacific Ocean, I. 214.

V.

Variation of the Magnetic Inclination, discussion of the secular, in the Northeastern States. C. A. Schott, I. 177.
Variation, supplement to the paper on the secular, in the magnetic declination on the Atlantic and Gulf Coast of the United States, from observations in the 17th, 18th, and 19th centuries, published in the Providence Proceedings of the Association. C. A. Schott, I. 173.
Vaughan, Daniel. The stability of satellites revolving in small orbits, I. 111.
Visual Direction, some experiments on. J. Brocklesby, I. 139.
Vital Statistics. E. B. Elliott, I. 50.
Volumes on hand, II. 251.
Votes of thanks, II. 240.

W.

Weinland, David F. On the digestive apparatus of the Acanthocephala, II. 197.
——— On the names of animals and plants, with reference to the origin of languages, and to the countries where nations passed their childhood, II. 193.
Whirlwinds and Tornadoes, on the spirality of motion in. W. C. Redfield, I. 212.
Winchell, A. Notes on the geology of Middle and Southern Alabama, II. 82.
——— Statistics of some Artesian wells of Alabama, II. 94.
Wyman, J. Note on the teeth of an elephant discovered near Zanesville, Ohio, II. 169.
——— On a batrachian reptile from the coal formation, II. 172.

ERRATA.

PART I.

Page 54, line 6 from bottom, *after* Liverpool *read* and Manchester.

" 55, in first table, *for* .024 *and* .088 *read* .025 *and* .090.

" 60, lines 10 and 20, *for* $\int$ *read* $\int_0^x$.

" 66, last line, *for* $d_{0|x}$ *read* $\delta_{0|x}$.

" 73, last line, *for* 1.803755 *read* $\bar{1}$.803755.

" 95, supply 12 as denominator in the last formula.

PART II.

Page 33, line 1, *for* Cuchillo *read* Cuchilla.

" 39, " 33, " Altis " Celtis.

" 40, " 5, " cross " cropp.

" " " 34, " mosquito " moezquite.

" 42, " 12, " Lóbota " Cóbota.

" 44, " 3, " Liénagas " Ciénagas.

" " " 29, 38, &c., *for* Guehibabi *read* Juchibabi.

" 45, " 7, *for* di *read* del.

" " " 26, " Papaga " Papago.

" 47, " 6, " marshes " mashes.

" 49, " 29, " Pinajas " Tinajas.

" 50, lines 20 and 21, *for* is almost dry, and active to change, *read* is almost day and night busy to change.

" 74, line 33, *for the equation* $\frac{4 \times 0\,8}{0\,P}$ *read* $\frac{4 \times 0\,8}{\sqrt{0\,P}}$.

" 177, " 21, *for* Retchporea *read* Retepora.

" " " 33, " aux saillant *read* aux angles saillants.

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